

**UV-VIS RADIATION CURABLE COATING COMPOSITIONS COMPRISING MAGNETIC OR  
MAGNETIZABLE PIGMENT PARTICLES AND METHODS FOR PRODUCING OPTICAL EFFECT  
LAYERS**

5 **FIELD OF THE INVENTION**

[001] The present invention relates to the field of UV-Vis radiation curable coating compositions comprising magnetic or magnetizable pigment particles and methods for producing optical effect layers (OELs) comprising magnetically oriented magnetic or magnetizable pigment particles and the use of said OELs as anti-counterfeit means on security documents or security articles as well as decorative purposes.

**BACKGROUND OF THE INVENTION**

[002] It is known in the art to use inks, compositions, coatings or layers containing oriented magnetic or magnetizable pigment particles, particularly also optically variable magnetic or magnetizable pigment particles, for the production of security elements, e.g. in the field of security documents. Coatings or layers comprising oriented magnetic or magnetizable pigment particles are disclosed for example in US 2,570,856; US 3,676,273; US 3,791,864; US 5,630,877 and US 5,364,689. Coatings or layers comprising oriented magnetic color-shifting pigment particles, resulting in particularly appealing optical effects, useful for the protection of security documents, have been disclosed in WO 2002/090002 A2 and WO 2005/002866 A1.

20 [003] Security features, e.g. for security documents, can generally be classified into "covert" security features on the one hand, and "overt" security features on the other hand. The protection provided by covert security features relies on the principle that such features are difficult to detect, typically requiring specialized equipment and knowledge for detection, whereas "overt" security features rely on the concept of being easily detectable with the unaided human senses, e.g. such features may be visible and/or detectable via the tactile sense while still being difficult to produce and/or to copy. However, the effectiveness of overt security features depends to a great extent on their easy recognition as a security feature.

30 [004] Magnetic or magnetizable pigment particles in printing inks or coatings allow for the production of magnetically induced images, designs and/or patterns through the application of a correspondingly structured magnetic field, inducing a local orientation of the magnetic or magnetizable pigment particles in the not yet hardened (i.e. wet) coating, followed by the hardening of the coating. The result is a fixed and stable magnetically induced image, design or pattern. Materials and technologies for the orientation of magnetic or magnetizable pigment particles in coating compositions have been disclosed for example in US 2,418,479; US 2,570,856; US 3,791,864, DE 2006848-A, US 3,676,273, US 5,364,689, US 6,103,361, EP 0 406 667 B1; US 2002/0160194; US 2004/0009309; EP 0 710 508 A1; WO 2002/09002 A2; WO 2003/000801 A2; WO 2005/002866 A1; WO 2006/061301 A1. In such a way, magnetically induced patterns which are highly resistant to counterfeit can be produced. The security element in question can only be produced by having access to both, the magnetic or magnetizable pigment particles or the corresponding ink, and the particular technology employed to print said ink and to orient said pigment in the printed ink.

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**[005]** However, a need remains for performing UV-Vis radiation curable coating compositions comprising magnetic or magnetizable pigment particles and methods to produce optical effect layers, said optical effects layers exhibiting an eye-catching effect and being mechanically robust.

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# SUMMARY OF THE INVENTION

**[006]** Accordingly, it is an object of the present invention to overcome the deficiencies of the prior art. This is achieved by the provision of UV-Vis radiation curable coating compositions comprising:

- i) optionally one or more (meth)acrylate oligomers in a total amount between about 0 wt.% and about 10 wt.%, preferably between about 1 wt.% and about 10 wt.%;
- 10 ii) one or more (meth)acrylate monomers, preferably selected from the group consisting of tri(meth)acrylates, tetra(meth)acrylates and mixtures thereof, in a total amount between about 1 wt.% and about 20 wt.%, wherein said monomers are different from the (meth)acrylate oligomers of i);
- iii) one or more cyclic ether compounds, preferably selected from the group consisting of epoxides, oxetanes and mixtures thereof, more preferably cycloaliphatic epoxides, oxetanes and mixtures thereof,
- 15 in a total amount between about 5 wt.% and about 40 wt.%;
- iv) one or more vinyl ether compounds in a total amount between about 10 wt.% and about 50 wt.%;
- v) one or more onium photoinitiators in a total amount between about 0.1 wt.% and about 10 wt.%;
- vi) one or more photoinitiators selected from the group consisting of alkoxyketones, acetophenones, benzophenones, ketosulfones, benzyl ketals, benzoin ethers, phosphine oxides, phenylglyoxylates,
- 20 coumarins, camphorquinones and mixtures thereof in a total amount between about 0.1 wt.% and about 10 wt.%;
- vii) one or more thermoplastic polymers in a total amount between about 1 wt.% and about 20 wt.%;
- and
- viii) non-spherical magnetic or magnetisable pigment particles in a total amount between about 1 wt.%
- 25 and about 40 wt.%,

the weight percents being based on the total weight of the UV-Vis radiation curable coating composition.

**[007]** Preferably, the UV-Vis radiation curable coating composition described herein comprises:

- i) the one or more (meth)acrylate oligomers described herein being present in a total amount between about 2 wt.% and 5 wt.%;
- 30 ii) the one or more (meth)acrylate monomers described herein being present in a total amount between about 2 wt.% and 15 wt.%;
- iii) the one or more cyclic ether compounds described herein being present in a total amount between about 10 wt.% and 35 wt.%;
- iv) the one or more vinyl ether compounds described herein being present in a total amount between
- 35 about 15 wt.% and 40 wt.%;
- v) the one or more onium photoinitiators described herein being present in a total amount between about 1 wt.% and 5 wt.%;
- vi) the one or more photoinitiators selected from the group consisting of alkoxyketones, acetophenones, benzophenones, ketosulfones, benzyl ketals, benzoin ethers, phosphine oxides, phenylglyoxylates,

coumarins, camphorquinones and mixtures thereof described herein being in a total amount between about 1 wt.% and 5 wt.%;

vii) the one or more thermoplastic polymers described herein being in a total amount between about 3 wt.% and 15 wt.%; and

5 viii) the non-spherical magnetic or magnetisable pigment particles are present in a total amount between about 3 wt.% and 35 wt.%;

the weight percents being based on the total weight of the UV-Vis radiation curable coating composition.

**[008]** The UV-Vis radiation curable coating composition described herein may further comprise:

10 ix) optionally one or more photosensitizers, when present, said one or more photosensitizers are preferably present in a total amount from about 0.1 wt.% about 5 wt.%; and/or

x) optionally one or more fillers or extenders, when present, said one or more fillers or extenders are preferably present in a total amount from about 0.1 wt.% to about 10 wt.%; and/or

xi) optionally one or more UV stabilizers, when present, said one or more UV stabilizers are preferably present in a total amount from about 0.1 wt.% to about 10 wt.%; and/or

15 xii) optionally one or more color constant coloring components, when present, said one or more constant coloring components are preferably present in a total amount from about 0.05 wt.% to about 5 wt.%;

xiii) optionally one or more solvents, when present said one or more solvents are present in a total amount less than about 15 wt.%; and/or

20 xiv) optionally one or more marker substances or taggants and/or one or more machine readable materials; and/or

xv) optionally one or more additives selected from the group consisting of thickeners, surfactants, anti-settling agents, plasticizers, antifoaming agents, waxes and mixtures thereof;

the weight percents being based on the total weight of the UV-Vis radiation curable coating composition.

25 **[009]** Also described herein are methods for producing optical effect layers (OELs), said method comprising the steps of a) of applying the UV-Vis radiation curable coating composition on a substrate, b) exposing the coating layer which is in a first state to the magnetic field of a magnetic-field-generating device, thereby orienting at least a part of the non-spherical magnetic or magnetisable pigment particles described herein, and c) hardening the coating layer to a second state so as to fix the non-spherical magnetic or magnetisable pigment particles in their adopted positions and orientations.

30 **[010]** Also described herein are optical effect layers (OELs) produced by the method described herein and security documents as well as decorative elements and objects comprising one or more optical OELs described herein.

35 **[011]** Also described herein are methods of manufacturing a security document or a decorative element or object, comprising a) providing a security document or a decorative element or object, and b) providing an optical effect layer such as those described herein, in particular such as those obtained by the method described herein, so that it is comprised by the security document or decorative element or object.

40 **[012]** The UV-Vis radiation curable coating compositions described herein are particularly suitable for producing mechanically and chemically resistant optical effect layers (OELs) on demanding documents such as value documents including for example banknotes, said demanding documents being exposed

to mechanical constraints, such as e.g. folding, crumpling, creasing of their substrates and chemical constraints thus reducing their lifetime and thereby requesting an increasing replacement rate at additional costs. Furthermore, the UV-Vis radiation curable coating compositions described herein allow the manufacture of said highly durable optical effect layers (OELs) on value documents, wherein said

5 OELs can be produced in an efficient way in terms of speed and drying performance.

#### **BRIEF DESCRIPTION OF DRAWINGS**

**[013]** Figs 1-4 schematically illustrate the present invention and are not true to scale. The optical effect layers (OELs) produced by the UV-Vis radiation curable coating compositions are described in more detail with reference to the drawings and to particular embodiments, wherein

10 **Fig. 1** shows photographic images of OELs produced with comparative compositions (C1-C3) and UV-Vis radiation curable coating compositions according to the present invention (E1-E2).

**Fig. 2** shows photographic images of OELs produced with comparative compositions (C2-C3) and UV-Vis radiation curable coating compositions according to the present invention (E1-E2) after a dry crumpling test described herein (mechanical resistance test).

15 **Fig. 3** shows photographic images of OELs produced with comparative composition (C2) and UV-Vis radiation curable coating compositions according to the present invention (E1-E2) after a washing machine test described herein (mechanical resistance test).

**Figs 4** schematically illustrate the magnetic assembly used to produce the OELs shown in Fig. 1.

#### **DETAILED DESCRIPTION**

##### **Definitions**

**[014]** The following definitions are to be used to interpret the meaning of the terms discussed in the description and recited in the claims.

**[015]** As used herein, the term "at least one" is meant to define one or more than one, for example one or two or three.

25 **[016]** As used herein, the term "about" means that the amount or value in question may be the specific value designated or some other value in its neighborhood. Generally, the term "about" denoting a certain value is intended to denote a range within  $\pm 5\%$  of the value. As one example, the phrase "about 100" denotes a range of  $100 \pm 5$ , i.e. the range from 95 to 105. Generally, when the term "about" is used, it can be expected that similar results or effects according to the invention can be obtained within a range

30 of  $\pm 5\%$  of the indicated value.

**[017]** As used herein, the term "and/or" means that either all or only one of the elements of said group may be present. For example, "A and/or B" shall mean "only A, or only B, or both A and B". In the case of "only A", the term also covers the possibility that B is absent, i.e. "only A, but not B".

**[018]** The term "comprising" as used herein is intended to be non-exclusive and open-ended. Thus,

35 for instance a coating composition comprising a compound A may include other compounds besides A. However, the term "comprising" also covers, as a particular embodiment thereof, the more restrictive meanings of "consisting essentially of" and "consisting of", so that for instance "a fountain solution comprising A, B and optionally C" may also (essentially) consist of A and B, or (essentially) consist of A, B and C.

[019] The term "optical effect layer (OEL)" as used herein denotes a coating layer that comprises oriented magnetic or magnetizable pigment particles, wherein said magnetic or magnetizable pigment particles are oriented by a magnetic field and wherein the oriented magnetic or magnetizable pigment particles are fixed/frozen in their orientation and position (i.e. after curing) so as to form a magnetically induced image.

[020] The term "coating composition" refers to any composition which is capable of forming an optical effect layer (OEL) on a solid substrate and which can be applied preferably but not exclusively by a printing method.

[021] As used herein, the term "wet" refers to a coating layer which is not yet cured, for example a coating in which the non-spherical magnetic or magnetizable pigment particles are still able to change their positions and orientations under the influence of external forces acting upon them.

[022] The term "security document" refers to a document which is usually protected against counterfeit or fraud by at least one security feature. Examples of security documents include without limitation value documents and value commercial goods.

[023] The term "security feature" is used to denote an image, pattern or graphic element that can be used for authentication purposes.

[024] Where the present description refers to "preferred" embodiments/features, combinations of these "preferred" embodiments/features shall also be deemed as disclosed as long as this combination of "preferred" embodiments/features is technically meaningful.

[025] The UV-Vis radiation curable coating composition described herein may comprise i) one or more (meth)acrylate oligomers, when present said one or more (meth)acrylate oligomers are present in a total amount between about 1 wt.% and 10 wt.%, preferably between about 2 wt.% and 5 wt.%, the weight percents being based on the total weight of the radiation curable coating composition. According to one embodiment, the UV-Vis radiation curable coating composition described herein comprises i) the (meth)acrylate oligomers in the amount described herein. (Meth)acrylate oligomers as used herein refers to relatively high molecular weight compounds having a weight average molecular weight (MW)  $\geq 300$  g/mol, preferably  $\geq 500$  g/mol. The (meth)acrylate oligomers may be branched or essentially linear, and the (meth)acrylate functional group or groups, respectively, can be terminal groups and/or pendant side groups bonded to the oligomer backbone. Preferably, the (meth)acrylate oligomers are selected from the group consisting of (meth)acrylic oligomers, urethane (meth)acrylate oligomers, polyester (meth)acrylate oligomers, polyether based (meth)acrylate oligomers, epoxy (meth)acrylate oligomers, and mixtures thereof, more preferably selected from the group consisting of epoxy (meth)acrylate oligomers and mixtures thereof.

[026] The term "(meth)acrylate" in the context of the present invention refers to the acrylate as well as the corresponding methacrylate.

[027] The UV-Vis radiation curable coating composition described herein comprises ii) one or more (meth)acrylate monomers, in a total amount from about 1 wt.% to about 20 wt.%, preferably from about 2 wt.% to about 15 wt.%, wherein said one or more monomers are different from the (meth)acrylate oligomers of i), the weight percents being based on the total weight of the UV-Vis radiation curable coating composition. Preferably, the one or more (meth)acrylates described herein are selected from

the group consisting of epoxy (meth)acrylates, (meth)acrylated oils, polyester and polyether (meth)acrylates, aliphatic or aromatic urethane (meth)acrylates, silicone (meth)acrylates, acrylic (meth)acrylates and mixtures thereof. Suitable examples of (meth)acrylates include tri(meth)acrylates, tetra(meth)acrylates and mixtures thereof.

- 5 **[028]** Suitable examples of tri(meth)acrylates include without limitation trimethylolpropane triacrylates, trimethylolpropane trimethacrylates; alkoxyated (in particular ethoxylated or propoxylated) trimethylolpropane triacrylates; alkoxyated (in particular ethoxylated or propoxylated) trimethylolpropane trimethacrylates; alkoxyated (in particular ethoxylated or propoxylated) glycerol triacrylates; pentaerythritol triacrylates; alkoxyated (in particular ethoxylated or propoxylated) pentaerythritol triacrylates and mixtures thereof; preferably selected from the group consisting of trimethylolpropane triacrylates; alkoxyated (in particular ethoxylated or propoxylated) trimethylolpropane triacrylates; alkoxyated (in particular ethoxylated or propoxylated) glycerol triacrylates; pentaerythritol triacrylates and mixtures thereof.

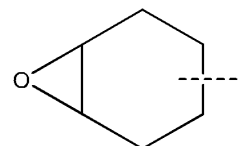
- 10 **[029]** Suitable examples of tetra(meth)acrylates include without limitation ditrimethylolpropane tetra(meth)acrylates; pentaerythritol tetra(meth)acrylates; alkoxyated (such as for example ethoxylated and propoxylated) pentaerythritol tetra(meth)acrylates and mixtures thereof; preferably selected from the group consisting of ditrimethylolpropane tetra(meth)acrylates; alkoxyated pentaerythritol tetra(meth)acrylates and mixtures thereof.

- 15 **[030]** The UV-Vis radiation curable coating composition described herein may further comprise one or more UV-Vis curable diluents selected from the group consisting of mono(meth)acrylates; di(meth)acrylates and mixtures thereof. Suitable examples of mono(meth)acrylates include without limitation alkyl (meth)acrylates; cycloalkyl (meth)acrylates; benzyl (meth)acrylates; phenyl (meth)acrylates (including phenoxyalkyl (meth)acrylates such as phenoxyethyl acrylate); cyclic trimethylolpropane formal acrylate; tetrahydrofurfuryl acrylate; aliphatic urethane (meth)acrylates and alkoxyated (in particular ethoxylated or propoxylated) compounds thereof. Suitable examples of di(meth)acrylates include without limitation ethylene glycol diacrylate; ethylene glycol dimethacrylate; 1,4-butanediol diacrylate; 1,4-butanediol dimethacrylate; 1,3-butanediol diacrylate; 1,3-butanediol dimethacrylate; 2-methyl-1,3-propanediol diacrylate; 3-methyl-1,5-pentanediol diacrylate; 2-butyl-2-ethyl-1,3-propanediol diacrylate; 1,6-hexanediol diacrylate; 1,6-hexanediol dimethacrylate; neopentyl glycol diacrylate; neopentyl glycol dimethacrylate; 1,9-nonanediol diacrylate; 1,9-nonanediol dimethacrylate; 1,10-decanediol diacrylate; 1,10-decanediol dimethacrylate; alkoxyated (in particular ethoxylated and propoxylated) 1,6-hexanediol diacrylates; propoxylated neopentyl glycol diacrylate; ethoxylated 2-methyl-1,3-propanediol diacrylate; tricyclodecanedimethanol diacrylate); diethylene glycol diacrylate; diethylene glycol dimethacrylate; dipropylene glycol diacrylate; triethylene glycol diacrylate; triethylene glycol dimethacrylate; tripropylene glycol diacrylate; tripropylene glycol dimethacrylate; tetraethylene glycol diacrylate; tetraethylene glycol dimethacrylate; polyethylene glycol 200/400/600 diacrylates; polyethylene glycol 200/400/600 dimethacrylate; ethoxylated (EO2/EO3/EO4/EO10) bisphenol A diacrylates; and ethoxylated (EO2/EO3/EO4/EO10) bisphenol A dimethacrylate.

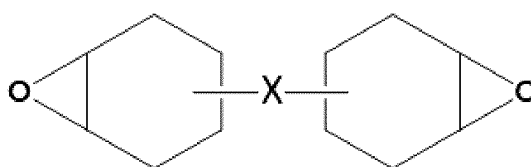
- 20 **[031]** The UV-Vis radiation curable coating composition described herein comprises iii) one or more cyclic ether compounds, preferably selected from the group consisting of epoxides, oxetanes and

mixtures thereof, more preferably cycloaliphatic epoxides, oxetanes and mixtures thereof, in a total amount between about 5 wt.% and about 40 wt.%, preferably between about 10 wt.% and about 35 wt.%, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition.

- 5 **[032]** According to one embodiment, the UV-Vis radiation curable coating composition described herein comprises at least one cyclic ether compound, preferably at least one cycloaliphatic epoxide, wherein said cycloaliphatic epoxide may be difunctional or polyfunctional. The UV-Vis radiation curable coating composition herein comprising the at least one cycloaliphatic epoxide described herein may further comprise at least one oxetane described herein, wherein said at least one cycloaliphatic epoxide and said at least one oxetane are present in a total amount from about 5 wt.% to about 40 wt.%, preferably from about 10 wt.% to about 35 wt.%, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition. As well known by the person skilled in the art, a cycloaliphatic epoxide is a cationically curable monomer containing at least a substituted or unsubstituted epoxycyclohexyl residue:



- 15 **[033]** Preferably, the cycloaliphatic epoxide described herein comprises at least one cyclohexane ring, and/or at least two epoxide groups, preferably at least one cyclohexane ring, and at least two epoxide groups. Preferred cycloaliphatic epoxides comprise more than one (i.e. at least two) cyclohexane groups and preferably have the structural formula (I):

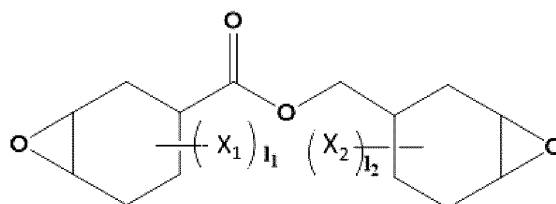


(I)

- 20 wherein  $-X-$  represents a single bond or a divalent group comprising one or more atoms. The cycloaliphatic epoxide of general formula (I) is optionally substituted by one or more linear or branched alkyl radicals containing from one to ten carbon atoms (such as methyl, ethyl, *n*-propyl, *i*-propyl, *n*-butyl, *i*-butyl, *s*-butyl, *t*-butyl, hexyl, octyl, and decyl), and preferably containing from one to three carbon atoms (such as methyl, ethyl, *n*-propyl, and *i*-propyl).
- 25 **[034]** According to one embodiment,  $-X-$  is a divalent hydrocarbon group which may be a straight- or branched-chain alkylene group comprising from one to eighteen carbon atoms, wherein examples of said straight- or branched-chain alkylene group include without limitation methylene group, methylenemethylene group, dimethylenemethylene group, ethylene group, propylene group, and trimethylenemethylene group.
- 30 **[035]** According to one embodiment,  $-X-$  is a divalent alicyclic hydrocarbon group or cycloalkylidene

group such as 1,2-cyclopentylene group, 1,3-cyclopentylene group, cyclopentylidene group, 1,2-cyclohexylene group, 1,3-cyclohexylene group, 1,4-cyclohexylene group, and cyclohexylidene group.

**[036]** According to one embodiment,  $-X-$  is a divalent group comprising one or more oxygen-containing linkage groups, wherein said oxygen-containing linkage groups are selected from the group consisting of  $-C(=O)-$ ,  $-OC(=O)O-$ ,  $-C(=O)O-$ , and  $-O-$ . Preferably, the cycloaliphatic epoxide is a cycloaliphatic epoxide of general formula (II), wherein  $-X-$  is a divalent group comprising one or more oxygen-containing linkage groups, wherein said oxygen-containing linkage groups are selected from the group consisting of  $-C(=O)-$ ,  $-OC(=O)O-$ ,  $-C(=O)O-$ , and  $-O-$ , and more preferably a cycloaliphatic epoxide of general formula (I-a), (I-b), or (I-c), as defined below:



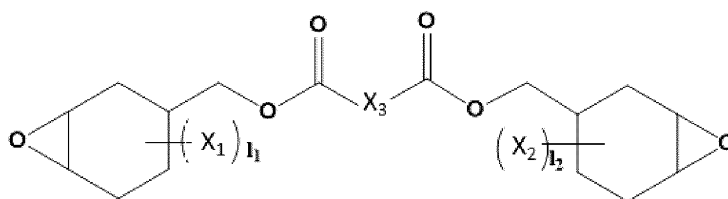
(I-a)

wherein

$X_1$  can be the same, or different in each occurrence and is a linear or branched alkyl radical containing from one to ten carbon atoms (such as methyl, ethyl, *n*-propyl, *i*-propyl, *n*-butyl, *i*-butyl, *s*-butyl, *t*-butyl, hexyl, octyl, and decyl), and preferably containing from one to three carbon atoms (such as methyl, ethyl, *n*-propyl, and *i*-propyl);

$X_2$  can be the same, or different in each occurrence and is a linear or branched alkyl radical containing from one to ten carbon atoms (such as methyl, ethyl, *n*-propyl, *i*-propyl, *n*-butyl, *i*-butyl, *s*-butyl, *t*-butyl, hexyl, octyl, and decyl), and preferably containing from one to three carbon atoms (such as methyl, ethyl, *n*-propyl, and *i*-propyl); and

$l_1$  and  $l_2$  are independently of each other integers comprised between 0 and 9, preferably comprised between 0 and 3, and more preferably 0;



(I-b)

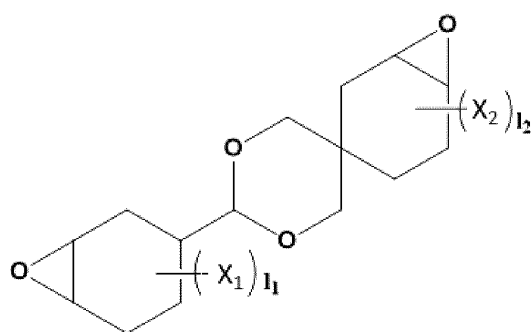
wherein

$X_1$  can be the same, or different in each occurrence and is a linear or branched alkyl radical containing from one to ten carbon atoms (such as methyl, ethyl, *n*-propyl, *i*-propyl, *n*-butyl, *i*-butyl, *s*-butyl, *t*-butyl, hexyl, octyl, and decyl), and preferably containing from one to three carbon atoms (such as methyl, ethyl, *n*-propyl, and *i*-propyl);

X<sub>2</sub> can be the same, or different in each occurrence and is a linear or branched alkyl radical containing from one to ten carbon atoms (such as methyl, ethyl, *n*-propyl, *i*-propyl, *n*-butyl, *i*-butyl, *s*-butyl, *t*-butyl, hexyl, octyl, and decyl), and preferably containing from one to three carbon atoms (such as methyl, ethyl, *n*-propyl, and *i*-propyl); and

- 5 I<sub>1</sub> and I<sub>2</sub> are independently of each other integers comprised between 0 and 9, preferably comprised between 0 and 3, and more preferably 0;

—X<sub>3</sub>— is a single bond or a linear or branched divalent hydrocarbon group containing from one to ten carbon atoms, and preferably containing from three to eight carbon atoms, such as alkylene groups including trimethylene, tetramethylene, hexamethylene, and 2-ethylhexylene, and cycloalkylene groups  
 10 such as 1,2-cyclohexylene group, 1,3-cyclohexylene group, and 1,4-cyclohexylene group, and cyclohexylidene group;



(I-c)

wherein

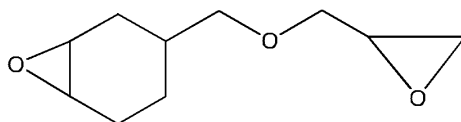
- 15 X<sub>1</sub> can be the same, or different in each occurrence and is a linear or branched alkyl radical containing from one to three carbon atoms, such as methyl, ethyl, *n*-propyl, and *i*-propyl;  
 X<sub>2</sub> can be the same, or different in each occurrence and is a linear or branched alkyl radical containing from one to three carbon atoms, such as methyl, ethyl, *n*-propyl, and *i*-propyl; and  
 I<sub>1</sub> and I<sub>2</sub> are independently of each other integers comprised between 0 and 9, preferably comprised  
 20 between 0 and 3, and more preferably 0.

- [037]** Preferred cycloaliphatic epoxides of general formula (I-a) include, but are not limited to 3,4-epoxycyclohexylmethyl-3,4-epoxycyclohexanecarboxylate; 3,4-epoxy-6-methyl-cyclohexylmethyl-3,4-epoxy-6-methylcyclohexanecarboxylate; 3,4-epoxy-2-methyl-cyclohexylmethyl-3,4-epoxy-2-methyl-cyclohexanecarboxylate; and 3,4-epoxy-4-methyl-cyclohexylmethyl-3,4-epoxy-4-methylcyclohexanecarboxylate.  
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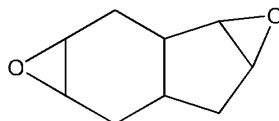
**[038]** Preferred cycloaliphatic epoxides of general formula (I-b) include, but are not limited to bis(3,4-epoxycyclohexylmethyl)adipate; bis(3,4-epoxy-6-methylcyclohexylmethyl)adipate, bis(3,4-epoxycyclohexylmethyl)oxalate; bis(3,4-epoxycyclohexylmethyl) pimelate; and bis(3,4-epoxycyclohexylmethyl)sebacate.

- 30 **[039]** Further cycloaliphatic epoxides include a cycloaliphatic epoxide of general formula (II-a) and a cycloaliphatic epoxide of general formula (II-b), which are optionally substituted by one or more linear or branched alkyl groups containing from one to ten carbon atoms (such as methyl, ethyl, *n*-propyl, *i*-

propyl, *n*-butyl, *i*-butyl, *s*-butyl, *t*-butyl, hexyl, octyl, and decyl), and preferably containing from one to three carbon atoms (such as methyl, ethyl, *n*-propyl, and *i*-propyl)



(II-a)



(II-b).

**[040]** The cycloaliphatic epoxides described herein may be hydroxy modified or (meth)acrylate modified.

**[041]** Oxetane compounds are known in the art to accelerate curing and reduce tackiness, thus limiting the risk of blocking and set-off when the printed sheets are put in stacks just after printing and curing. Preferred examples of oxetanes include trimethylene oxide; 3,3-dimethyloxetane; trimethylolpropane oxetane; 2-ethyl-2-hydroxymethyl oxetane; 3-ethyl-3-hydroxymethyl oxetane; 3-ethyl-3-[(2-ethylhexyloxy) methyl]oxetane; 3,3-dicyclomethyl oxetane; 3-ethyl-3-phenoxyethyl oxetane; bis ([1-ethyl(3-oxetanyl)]methyl) ether; 1,4-bis [3-ethyl-3-oxetanyl methoxy]methyl]benzene; 3,3-dimethyl-2(p-methoxy-phenyl)-oxetane; 3-ethyl-[(tri-ethoxysilyl propoxy)methyl]oxetane; 4,4-bis(3-ethyl-3-oxetanyl)methoxymethyl]biphenyl and 3,3-dimethyl-2(p-methoxy-phenyl) oxetane. The one or more oxetanes described herein may be hydroxy modified or (meth)acrylate modified. The term “(meth)acrylate” in the context of the present invention refers to the acrylate as well as the corresponding methacrylate.

**[042]** The UV-Vis radiation curable coating composition described herein comprises iv) one or more vinyl ether compounds in a total amount between about 10 wt.% and about 50 wt.%, preferably between about 15 wt.% and about 40 wt.%, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition. Vinyl ether compounds are known in the art to accelerate curing and reduce tackiness, thus limiting the risk of blocking and set-off when the printed substrates are put in stacks just after printing and curing.

**[043]** Examples of preferred vinyl ether compounds include methyl vinyl ether; ethyl vinyl ether; *n*-propyl vinyl ether; *n*-butyl vinyl ether; *iso*-butyl vinyl ether; ethylhexyl vinyl ether; octadecyl vinyl ether; dodecyl vinyl ether; isopropyl vinyl ether; *tert*-butyl vinyl ether; *tert*-amyl vinyl ether; cyclohexyl vinyl ether; cyclohexanedimethanol monovinyl ether; cyclohexanedimethanol divinyl ether; 4-(vinyl oxy methyl)cyclohexylmethyl benzoate; phenyl vinyl ether; methylphenyl vinyl ether; methoxyphenyl vinyl ether; 2-chloroethyl vinyl ether; 2-hydroxyethyl vinyl ether; 4-hydroxybutyl vinyl ether; 1,6-hexanediol monovinyl ether; ethylene glycol divinyl ether; ethylene glycol monovinyl ether; 1, 4-butanediol divinyl ether; 1,6-hexanediol divinyl ether; 4-(vinyl oxy)butyl benzoate; bis[4-(vinyl oxy)butyl]adipate; bis[4-

(vinyl)oxy)butyl)succinate; bis[4-(vinyl)oxymethyl]cyclohexylmethyl]glutarate; 4-(vinyl)oxy)butyl stearate; trimethylolpropane trivinyl ether; propenyl ether of propylene carbonate; diethylene glycol monovinyl ether; diethylene glycol divinyl ether; ethylene glycol butylvinyl ether; dipropylene glycol divinyl ether; triethylene glycol divinyl ether; triethylene glycol methyl vinyl ether; triethylene glycol monobutyl vinyl ether; tetraethylene glycol divinyl ether; poly(tetrahydrofuran) divinyl ether; polyethyleneglycol-520 methyl vinyl ether; pluriol-E200 divinyl ether; tris[4-(vinyl)oxy)butyl]trimellitate; 1,4-bis(2-vinyl)oxyethoxy)benzene; 2,2-bis(4-vinyl)oxyethoxyphenyl)propane; bis[4-(vinyl)oxy)methyl]cyclohexyl]methyl] terephthalate; bis[4-(vinyl)oxy)methyl]cyclohexyl]methyl] isophthalate. According to one embodiment, the UV-Vis radiation curable coating composition described herein comprises iv) two or more vinyl ether compounds in a total amount between about 10 wt.% and about 50 wt.%, preferably between about 15 wt.% and about 40 wt.%, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition.

**[044]** The UV-Vis radiation curable coating composition described herein comprises v) one or more onium photoinitiators in a total amount between about 0.1 wt.% and about 10 wt.%, preferably between about 1 wt.% and about 5 wt.%, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition. The one or more onium salts described herein are preferably selected from the group consisting of azonium salts, oxonium salts, iodonium salts, sulfonium salts and mixtures thereof, more preferably selected from the group consisting of oxonium salts, iodonium salts, sulfonium salts and mixtures thereof, and still more preferably selected from the group consisting of iodonium salts, sulfonium salts and mixtures thereof.

**[045]** The one or more iodonium salts described herein have a cationic moiety and an anionic moiety, wherein the anionic moiety is preferably  $\text{BF}_4^-$ ,  $\text{B}(\text{C}_6\text{F}_5)_4^-$ ,  $\text{PF}_6^-$ ,  $(\text{PF}_{6-m}(\text{C}_n\text{F}_{2n-1})_m)^-$  (where m is an integer from 1 to 5, and n is an integer from 1 to 4),  $\text{AsF}_6^-$ ,  $\text{SbF}_6^-$ ,  $\text{CF}_3\text{SO}_3^-$ , perfluoroalkyl sulfonate or pentafluorohydroxyantimonate, more preferably  $\text{SbF}_6^-$ ,  $\text{PF}_6^-$  or  $\text{B}(\text{C}_6\text{F}_5)_4^-$  and wherein the cationic moiety is preferably an aromatic iodonium ion, more preferably a iodonium ion comprising two aryl groups, wherein the two aryl groups may be independently substituted by one or more alkyl groups (such as for example methyl, ethyl, isobutyl, tertbutyl, etc.) one or more alkoxy groups, one or more nitro groups, one or more halogen containing groups, one or more hydroxy groups or a combination thereof.

**[046]** The one or more sulfonium salts described herein have a cationic moiety and an anionic moiety, wherein the anionic moiety is preferably,  $\text{BF}_4^-$ ,  $\text{B}(\text{C}_6\text{F}_5)_4^-$ ,  $\text{PF}_6^-$ ,  $(\text{PF}_{6-m}(\text{C}_n\text{F}_{2n-1})_m)^-$  (where m is an integer from 1 to 5, and n is an integer from 1 to 4),  $\text{AsF}_6^-$ ,  $\text{SbF}_6^-$ ,  $\text{CF}_3\text{SO}_3^-$ , perfluoroalkyl sulfonate or pentafluorohydroxyantimonate, more preferably  $\text{SbF}_6^-$  or  $\text{PF}_6^-$  and wherein the cationic moiety is preferably an aromatic sulfonium ion, more preferably a sulfonium ion comprising two or more aryl groups, wherein the two or more aryl groups may be independently substituted by one or more alkyl groups (such as for example methyl, ethyl, isobutyl, tertbutyl, etc.) one or more alkoxy groups, one or more aryloxyl groups, one or more halogen containing groups, one or more hydroxy groups or a combination thereof.

**[047]** The UV-Vis radiation curable coating composition described herein comprises vi) one or more photoinitiators are selected from the group consisting of hydroxyketones (e.g. alpha-hydroxyketones), alkoxyketones (e.g. alpha-alkoxyketones), acetophenones, benzophenones, ketosulfones, benzyl

ketals, benzoin ethers, phosphine oxides, phenylglyoxylates, coumarins, camphorquinones and mixtures thereof, preferably hydroxyketones (e.g. alpha-hydroxyketones), in a total amount between about 0.1 wt.% and about 10 wt.%, preferably between about 1 wt.% and about 5 wt.%, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition. Preferably, the one or more photoinitiators vi) are selected from the group consisting of phosphine oxides, hydroxyketones, and mixtures thereof, more preferably hydroxyketones (e.g. alpha-hydroxyketones).

**[048]** The UV-Vis radiation curable coating composition described herein may further comprise ix) one or more photosensitizers. Photosensitizers are activated by one or more of the wavelengths emitted by the UV-Vis light source and reach an excited state. The excited photosensitizer either transfer energy to the one or more photoinitiators or an electron. Either process in turn initiates the polymerization process. The UV-Vis radiation curable coating composition described herein may further comprise one or more photosensitizers in conjunction with the one or more photoinitiators v) and vi) described herein in order to achieve efficient curing. Suitable examples of photosensitizers are known to those skilled in the art (e.g. in Industrial Photoinitiators, W. A. Green, CRC Press, 2010, Table 8.1 p. 170). Preferably, the one or more photosensitizers are selected from the group consisting of thioxanthone compounds, anthracene compounds, naphthalene compounds, titanocene compounds, and mixtures thereof; more preferably are selected from the group consisting of thioxanthone compounds (including without limitation isopropyl-thioxanthone (ITX), 1-chloro-2-propoxy-thioxanthone (CPTX), 2-chloro-thioxanthone (CTX) and 2,4-diethyl-thioxanthone (DETX) and mixtures thereof and oligomeric or polymeric forms thereof, anthracene compounds (such as 9,10-diethoxyanthracene and 9,10-dibutyloxyanthracene), naphthalene compounds (such as 1,4 diethoxynaphtalene), and mixtures thereof. When present, the one or more photosensitizers are preferably present in a total amount from about 0.1 wt.% to about 5 wt.% and still more preferably about 0.2 wt.% to about 1 wt.%, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition.

**[049]** The UV-Vis radiation curable coating composition described herein comprises vii) one or more thermoplastic polymers in a total amount between about 1 wt.% and about 20 wt.%, preferably between about 3 wt.% and about 15 wt.%, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition. Preferably, the one or more thermoplastic polymers are selected from the group consisting of polyvinyl butyrals (PVB), polyamides, polyvinyl chlorides (PVC), polyesters, polyacetals, polyolefins, styrenic polymers, polycarbonates, polyarylates, polyimides, polyether ether ketones (PEEK), polyetherketoneketones (PEKK), polyphenylene based resins, polysulphones and mixtures thereof, more preferably selected from the group consisting of polyvinyl butyrals (PVB) and mixtures thereof. According to one embodiment, at least one of the one or more thermoplastic polymers is polyvinyl butyral (PVB) and/or polyvinyl chloride (PVC).

**[050]** The UV-Vis radiation curable coating composition described herein comprises viii) non-spherical magnetic or magnetisable pigment particles in a total amount between about 1 wt.% and about 40 wt.%, preferably between about 3 wt.% and about 35 wt.%, more preferably between about 5 wt.% and about 30 wt.%, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition. The non-spherical magnetic or magnetizable pigment particles described herein are preferably prolate or oblate ellipsoid-shaped, platelet-shaped or needle-shaped magnetic or

magnetizable pigment particles or a mixture of two or more thereof and more preferably platelet-shaped particles.

[051] Non-spherical magnetic or magnetizable pigment particles described herein are defined as having, due to their non-spherical shape, non-isotropic reflectivity with respect to an incident electromagnetic radiation for which the cured binder material is at least partially transparent. As used herein, the term “non-isotropic reflectivity” denotes that the proportion of incident radiation from a first angle that is reflected by a particle into a certain (viewing) direction (a second angle) is a function of the orientation of the particles, i.e. that a change of the orientation of the particle with respect to the first angle can lead to a different magnitude of the reflection to the viewing direction. Preferably, the non-spherical magnetic or magnetizable pigment particles described herein have a non-isotropic reflectivity with respect to incident electromagnetic radiation in some parts or in the complete wavelength range of from about 200 to about 2500 nm, more preferably from about 400 to about 700 nm, such that a change of the particle's orientation results in a change of reflection by that particle into a certain direction. As known by the man skilled in the art, the magnetic or magnetizable pigment particles described herein are different from conventional pigments, in that said conventional pigment particles exhibit the same color and reflectivity, independent of the particle orientation, whereas the magnetic or magnetizable pigment particles described herein exhibit either a reflection or a color, or both, that depend on the particle orientation.

[052] The UV-Vis radiation curable coating composition described herein as well as the coating layer described herein comprise the non-spherical, preferably platelet-shaped, magnetic or magnetizable pigment particles described herein preferably in an amount from about 1 wt.% to about 40 wt.%, preferably between about 3 wt.% and about 35 wt.%, more preferably between about 5 wt.% and about 30 wt.%, the weight percentages being based on the total weight of the UV-Vis radiation curable coating composition or the coating layer.

[053] Suitable examples of non-spherical, preferably platelet-shaped, magnetic or magnetizable pigment particles described herein include without limitation pigment particles comprising a magnetic metal selected from the group consisting of cobalt (Co), iron (Fe), and nickel (Ni); a magnetic alloy of iron, manganese, cobalt, nickel or a mixture of two or more thereof; a magnetic oxide of chromium, manganese, cobalt, iron, nickel or a mixture of two or more thereof; or a mixture of two or more thereof. The term “magnetic” in reference to the metals, alloys and oxides is directed to ferromagnetic or ferrimagnetic metals, alloys and oxides. Magnetic oxides of chromium, manganese, cobalt, iron, nickel or a mixture of two or more thereof may be pure or mixed oxides. Examples of magnetic oxides include without limitation iron oxides such as hematite ( $\text{Fe}_2\text{O}_3$ ), magnetite ( $\text{Fe}_3\text{O}_4$ ), chromium dioxide ( $\text{CrO}_2$ ), magnetic ferrites ( $\text{MFe}_2\text{O}_4$ ), magnetic spinels ( $\text{MR}_2\text{O}_4$ ), magnetic hexaferrites ( $\text{MFe}_{12}\text{O}_{19}$ ), magnetic orthoferrites ( $\text{RFeO}_3$ ), magnetic garnets  $\text{M}_3\text{R}_2(\text{AO}_4)_3$ , wherein M stands for two-valent metal, R stands for three-valent metal, and A stands for four-valent metal.

[054] Examples of non-spherical, preferably platelet-shaped, magnetic or magnetizable pigment particles described herein include without limitation pigment particles comprising a magnetic layer M made from one or more of a magnetic metal such as cobalt (Co), iron (Fe), or nickel (Ni); and a magnetic alloy of iron, cobalt or nickel, wherein said magnetic or magnetizable pigment particles may be

multilayered structures comprising one or more additional layers. Preferably, the one or more additional layers are layers A independently made from one or more selected from the group consisting of metal fluorides such as magnesium fluoride ( $\text{MgF}_2$ ), silicon oxide ( $\text{SiO}$ ), silicon dioxide ( $\text{SiO}_2$ ), titanium oxide ( $\text{TiO}_2$ ), and aluminum oxide ( $\text{Al}_2\text{O}_3$ ), more preferably silicon dioxide ( $\text{SiO}_2$ ); or layers B independently  
5 made from one or more selected from the group consisting of metals and metal alloys, preferably selected from the group consisting of reflective metals and reflective metal alloys, and more preferably selected from the group consisting of silver (Ag), aluminum (Al), chromium (Cr), and nickel (Ni), and still more preferably aluminum (Al); or a combination of one or more layers A such as those described hereabove and one or more layers B such as those described hereabove. Typical examples of the  
10 platelet-shaped magnetic or magnetizable pigment particles being multilayered structures described hereabove include without limitation A/M multilayer structures, A/M/A multilayer structures, A/M/B multilayer structures, A/B/M/A multilayer structures, A/B/M/B multilayer structures, A/B/M/B/A multilayer structures, B/M multilayer structures, B/M/B multilayer structures, M/A/M multilayer structures, B/A/M/A multilayer structures, B/A/M/B multilayer structures, B/A/M/B/A multilayer structures, B/A/M/A/B  
15 multilayer structures, B/A/B/A/M/A/B/A/B multilayer structures, A/B/A/B/A/M/A/B/A/B multilayer structures, wherein the layers A, the magnetic layers M and the layers B are chosen from those described hereabove.

**[055]** The UV-Vis radiation curable coating composition described herein may comprise non-spherical, preferably platelet-shaped, optically variable magnetic or magnetizable pigment particles,  
20 and/or non-spherical, preferably platelet-shaped, magnetic or magnetizable pigment particles having no optically variable properties. Preferably, at least a part of the magnetic or magnetizable pigment particles described herein is constituted by non-spherical, preferably platelet-shaped, optically variable magnetic or magnetizable pigment particles. In addition to the overt security provided by the colorshifting property of the optically variable magnetic or magnetizable pigment particles, which allows easily detecting,  
25 recognizing and/or discriminating an article or security document carrying an ink, coating composition, or coating layer comprising the optically variable magnetic or magnetizable pigment particles described herein from their possible counterfeits using the unaided human senses, the optical properties of the optically variable magnetic or magnetizable pigment particles may also be used as a machine readable tool for the recognition of the OEL. Thus, the optical properties of the optically variable magnetic or  
30 magnetizable pigment particles may simultaneously be used as a covert or semi-covert security feature in an authentication process wherein the optical (e.g. spectral) properties of the pigment particles are analyzed and thus increase the counterfeiting resistance.

**[056]** The use of non-spherical, preferably platelet-shaped, optically variable magnetic or magnetizable pigment particles in coating layers for producing an OEL enhances the significance of the  
35 OEL as a security feature in security document applications, because such materials are reserved to the security document printing industry and are not commercially available to the public.

**[057]** As mentioned above, preferably at least a part of the non-spherical, preferably platelet-shaped, magnetic or magnetizable pigment particles is constituted by non-spherical, preferably platelet-shaped, optically variable magnetic or magnetizable pigment particles. These are more preferably selected from  
40 the group consisting of magnetic thin-film interference pigment particles, magnetic cholesteric liquid

crystal pigment particles, interference coated pigment particles comprising a magnetic material and mixtures of two or more thereof.

[058] Magnetic thin film interference pigment particles are known to those skilled in the art and are disclosed e.g. in US 4,838,648; WO 2002/073250 A2; EP 0 686 675 B1; WO 2003/000801 A2; US 5 6,838,166; WO 2007/131833 A1; EP 2 402 401 B1; WO 2019/103937 A1; EP 3 587 500 A1, EP 3 587 501 A1, EP 3 587 502 A1, EP 3 587503 A1, WO 2020/006286 A1, WO 2020/131700 A1, US 2021/0101402, US 2021/038812, US 2022/0282094, and in the documents cited therein. Preferably, the magnetic thin film interference pigment particles comprise pigment particles having a five-layer Fabry-Perot multilayer structure and/or pigment particles having a six-layer Fabry-Perot multilayer structure and/or pigment particles having a seven-layer Fabry-Perot multilayer structure and/or pigment particles having a nine-layer Fabry-Perot multilayer structure and/or pigment particles having an eleven-layer Fabry-Perot multilayer structure and/or pigment particles having a multilayer structure combining one or more multilayer Fabry-Perot structures.

[059] Preferred five-layer Fabry-Perot multilayer structures consist of 15 absorber/dielectric/reflector/dielectric/absorber multilayer structures wherein the reflector and/or the absorber is also a magnetic layer, preferably the reflector and/or the absorber is a magnetic layer comprising nickel, iron and/or cobalt, and/or a magnetic alloy comprising nickel, iron and/or cobalt and/or a magnetic oxide comprising nickel (Ni), iron (Fe) and/or cobalt (Co).

[060] Further preferred five-layer Fabry-Perot multilayer structures consist of 20 dielectric/reflector/magnetic/reflector/dielectric multilayer structures.

[061] Preferred six-layer Fabry-Perot multilayer structures consist of absorber/dielectric/reflector/magnetic/dielectric/absorber multilayer structures.

[062] Preferred seven-layer Fabry Perot multilayer structures consist of 25 absorber/dielectric/reflector/magnetic/reflector/dielectric/absorber multilayer structures such as disclosed in US 4,838,648.

[063] Preferred nine-layer Fabry-Perot multilayer structures consist of dielectric/absorber/dielectric/reflector/magnetic/dielectric/absorber/dielectric multilayer structures.

[064] Preferred eleven-layer Fabry-Perot multilayer structures consist of 30 absorber/dielectric/absorber/dielectric/reflector/magnetic/reflector/dielectric/absorber/dielectric/absorber multilayer structures.

[065] Preferably, the reflector layers described herein are independently made from one or more selected from the group consisting of metals and metal alloys, preferably selected from the group consisting of reflective metals and reflective metal alloys, more preferably selected from the group consisting of aluminum (Al), silver (Ag), copper (Cu), gold (Au), platinum (Pt), tin (Sn), titanium (Ti), 35 palladium (Pd), rhodium (Rh), niobium (Nb), chromium (Cr), nickel (Ni), and alloys thereof, even more preferably selected from the group consisting of aluminum (Al), chromium (Cr), nickel (Ni) and alloys thereof, and still more preferably aluminum (Al). Preferably, the dielectric layers are independently made from one or more selected from the group consisting of metal fluorides such as magnesium fluoride (MgF<sub>2</sub>), aluminum fluoride (AlF<sub>3</sub>), cerium fluoride (CeF<sub>3</sub>), lanthanum fluoride (LaF<sub>3</sub>), sodium aluminum 40 fluorides (e.g. Na<sub>3</sub>AlF<sub>6</sub>), neodymium fluoride (NdF<sub>3</sub>), samarium fluoride (SmF<sub>3</sub>), barium fluoride (BaF<sub>2</sub>),

calcium fluoride (CaF<sub>2</sub>), lithium fluoride (LiF), and metal oxides such as silicon oxide (SiO), silicon dioxide (SiO<sub>2</sub>), titanium oxide (TiO<sub>2</sub>), aluminum oxide (Al<sub>2</sub>O<sub>3</sub>), more preferably selected from the group consisting of magnesium fluoride (MgF<sub>2</sub>) and silicon dioxide (SiO<sub>2</sub>) and still more preferably magnesium fluoride (MgF<sub>2</sub>). Preferably, the absorber layers are independently made from one or more selected from the group consisting of aluminum (Al), silver (Ag), copper (Cu), palladium (Pd), platinum (Pt), titanium (Ti), vanadium (V), iron (Fe) tin (Sn), tungsten (W), molybdenum (Mo), rhodium (Rh), Niobium (Nb), chromium (Cr), nickel (Ni), metal oxides thereof, metal sulfides thereof, metal carbides thereof, and metal alloys thereof, more preferably selected from the group consisting of chromium (Cr), nickel (Ni), metal oxides thereof, and metal alloys thereof, and still more preferably selected from the group consisting of chromium (Cr), nickel (Ni), and metal alloys thereof. Preferably, the magnetic layer comprises nickel (Ni), iron (Fe) and/or cobalt (Co); and/or a magnetic alloy comprising nickel (Ni), iron (Fe) and/or cobalt (Co); and/or a magnetic oxide comprising nickel (Ni), iron (Fe) and/or cobalt (Co). When magnetic thin film interference pigment particles comprising a seven-layer Fabry-Perot structure are preferred, it is particularly preferred that the magnetic thin film interference pigment particles comprise a seven-layer Fabry-Perot absorber/dielectric/reflector/magnetic/reflector/dielectric/absorber multilayer structure consisting of a Cr/MgF<sub>2</sub>/Al/M/Al/MgF<sub>2</sub>/Cr multilayer structure wherein M is Ni, Fe or Co.

**[066]** The magnetic thin film interference pigment particles described herein may be multilayer pigment particles being considered as safe for human health and the environment and being based for example on five-layer Fabry-Perot multilayer structures, six-layer Fabry-Perot multilayer structures, seven-layer Fabry-Perot multilayer structures, nine-layer Fabry-Perot multilayer structures, eleven-layer Fabry-Perot multilayer structures and pigment particles having a multilayer structure combining one or more, or two or more, multilayer Fabry-Perot structures, wherein said pigment particles include one or more magnetic layers comprising a magnetic alloy having a substantially nickel-free composition including about 40 wt.% to about 90 wt.% iron, about 10 wt.% to about 50 wt.% chromium and about 0 wt.% to about 30 wt.% aluminum. Typical examples of multilayer pigment particles being considered as safe for human health and the environment can be found in EP 2 402 401 B1 whose content is hereby incorporated by reference in its entirety.

**[067]** Suitable magnetic cholesteric liquid crystal pigment particles exhibiting optically variable characteristics include without limitation magnetic monolayered cholesteric liquid crystal pigment particles and magnetic multilayered cholesteric liquid crystal pigment particles. Such pigment particles are disclosed for example in WO 2006/063926 A1, US 6,582,781 and US 6,531,221. WO 2006/063926 A1 discloses monolayers and pigment particles obtained therefrom with high brilliance and colorshifting properties with additional particular properties such as magnetizability. The disclosed monolayers and pigment particles, which are obtained therefrom by comminuting said monolayers, include a three-dimensionally crosslinked cholesteric liquid crystal mixture and magnetic nanoparticles. US 6,582,781 and US 6,410,130 disclose platelet-shaped cholesteric multilayer pigment particles which comprise the sequence A<sup>1</sup>/B/A<sup>2</sup>, wherein A<sup>1</sup> and A<sup>2</sup> may be identical or different and each comprises at least one cholesteric layer, and B is an interlayer absorbing all or some of the light transmitted by the layers A<sup>1</sup>

and A<sup>2</sup> and imparting magnetic properties to said interlayer. US 6,531,221 also discloses suitable platelet-shaped cholesteric multilayer pigment particles.

5 [068] Suitable interference coated pigment particles comprising one or more magnetic materials include without limitation structures consisting of a substrate selected from the group consisting of a  
10 core coated with one or more layers, wherein at least one of the core or the one or more layers have magnetic properties. For example, suitable interference coated pigment particles comprise a core made of a magnetic material such as those described hereabove, said core being coated with one or more layers made of one or more metal oxides, or they have a structure consisting of a core made of synthetic or natural micas, layered silicates (e.g. talc, kaolin and sericite), glasses (e.g. borosilicates), silicon  
15 dioxides (SiO<sub>2</sub>), aluminum oxides (Al<sub>2</sub>O<sub>3</sub>), titanium oxides (TiO<sub>2</sub>), graphites and mixtures of two or more thereof, said core being coated with one or more magnetic materials. Furthermore, one or more additional layers such as coloring layers may be present.

[069] The non-spherical, preferably platelet-shaped, magnetic or magnetizable pigment particles described herein preferably have a size d<sub>50</sub> between about 2 μm and about 50 μm (as measured by  
15 direct optical granulometry).

[070] The non-spherical, preferably platelet-shaped, magnetic or magnetizable pigment particles described herein may be surface treated so as to protect them against any deterioration that may occur in the coating composition and coating layer and/or to facilitate their incorporation in said coating composition and coating layer; typically corrosion inhibitor materials and/or wetting agents may be used.

20 [071] The UV-Vis radiation curable coating composition described herein may further comprise x) one or more fillers or extenders preferably selected from the group consisting of carbon fibers, talcs, mica (muscovite), wollastonites, calcinated clays, China clays, kaolins, carbonates (e.g. calcium carbonate, sodium aluminum carbonate), silicates (e.g. magnesium silicate, aluminum silicate), sulfates (e.g. magnesium sulfate, barium sulfate), titanates (e.g. potassium titanate), alumina hydrates, silica, fumed  
25 silica, montmorillonites, graphites, anatases, rutiles, bentonites, vermiculites, zinc whites, zinc sulfides, wood flours, quartz flours, natural fibers, synthetic fibers and combinations thereof. When present, the one or more fillers or extenders are preferably present in a total amount from about 0.1 wt.% to about 10 wt.%, more preferably from about 0.2 wt.% to about 5 wt.%, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition.

30 [072] The UV-Vis radiation curable coating composition described herein may further comprise xi) one or more UV stabilizers, in particular UV in-can stabilizers. When present, the one or more UV stabilizers are preferably present in a total amount from about 0.1 wt.% to about 10 wt.%, more preferably from about 0.2 wt.% to about 5 wt.%, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition. Examples of UV in-can stabilizers include without  
35 limitation glycerol alkoxylate (e.g. methoxylate, ethoxylate, propoxylate) poly acrylates, piperidin-1-oxyl and hydroquinones (including hydroquinone, alkyl substituted hydroquinones, alkoxy alkyl substituted hydroquinones). Suitable UV in-can stabilizers are for example sold by Rahn under the tradename GENORAD, by Kromachem under the tradename FLORSTAB, by 3Dresyns under the name 3D-ADD STAB2 Bio or by Sitech under the name SR-12UV.

**[073]** The UV-Vis radiation curable coating composition described herein may further comprise xii) one or more color constant coloring components (i.e. components having no optically variable properties) selected from the group consisting of organic pigment particles, inorganic pigment particles, and organic dyes. When present, the one or more constant coloring components are preferably present in a total amount from about 0.05 wt.% to about 5 wt.%, more preferably about 0.1 wt.% to about 3 wt.%, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition. Optically variable (also referred in the art as goniochromatic or colorshifting) pigment particles are known to exhibit a viewing-angle or incidence-angle dependent color. The optically variable pigment particles impart a different color impression at different viewing angles. By "different color impression", it is meant that the element exhibits a difference of at least one parameter of the CIELAB(1976) system, preferably exhibits a different "a\*" value, a different "L\*" value or a different "b\*" value or exhibits two or three different values chosen among "a\*", "b\*" and "L\*" values at different viewing angles. On the contrary to optically variable pigment particles that exhibit different colors or color impressions upon variation of the viewing angle, color constant coloring components do not exhibit a color change or color impression change upon variation of the viewing angle. For example, layers or coatings comprising optically variable pigment particles exhibit a colorshift upon variation of the viewing angle (e.g. from a viewing angle of about 90° with respect to the plane of the layer or coating to a viewing angle of about 22.5° with respect to the plane of the layer or coating) from a first color impression CI1 (e.g. green) to a second color impression CI2 (blue). According to one embodiment, the UV-Vis radiation curable coating composition described herein comprises the non-spherical, preferably platelet-shaped, optically variable magnetic or magnetizable pigment particles and one or more color constant coloring components. Preferably, the color of said one or more color constant coloring components is selected as being the same or similar to the color of the optically variable magnetic or magnetizable pigment particles at a first viewing angle (for example the first color impression CI1 being green) or being the same or similar to the color of the optically variable magnetic or magnetizable pigment particles at a second viewing angle (for example the second color impression CI2 being blue) or a color in between.

**[074]** The UV-Vis radiation curable coating composition described herein may further comprise xiii) one or more solvents to fine-tune the viscosity of said inks. Preferred solvents are polar aprotic solvents exhibiting a high boiling point such as carbonates. Preferred carbonates are alkylene carbonates (e.g. ethylene carbonates, propylene carbonates and butylene carbonates). Particularly preferred are propylene carbonates, which have a high boiling point and a favorable ecotoxicity profile. When present, the one or more solvents are present in a total amount less than about 15 wt.% and more preferably less than about 5 wt.%, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition.

**[075]** The UV-Vis radiation curable coating composition described herein may further comprise xiv) one or more marker substances or taggants and/or one or more machine readable materials selected from the group consisting of magnetic materials (different from the non-spherical magnetic or magnetizable pigment particles described herein), luminescent materials, electroluminescent materials, upconverting materials, electrically conductive materials, Raman active materials (including Surface-Enhanced Raman Spectroscopy SERS materials) and infrared-absorbing materials. Alternatively, the

one or more marker substances or taggants and/or one or more machine readable materials may be materials that can be authenticate by using a microscope. As used herein, the term "machine readable material" refers to a material which exhibits at least one distinctive property which is detectable by a device or a machine, and which can be comprised in a coating so as to confer a way to authenticate said coating or article comprising said coating by the use of a particular equipment for its detection and/or authentication.

5 [076] According to one embodiment, the UV-Vis radiation curable coating composition described herein comprises less than at or about 5 wt-%, preferably between at or about 0 wt-% and less than at or about 5 wt-% of a polyol having three or more hydroxyl groups per molecule and having a hydroxyl  
10 value of 550-750 mg KOH/g.

[077] The UV-Vis radiation curable coating composition described herein may further comprise xv) one or more additives including without limitation compounds and materials that are used for adjusting physical, rheological and chemical parameters of the coating composition such as the viscosity (e.g. thickeners and surfactants), the consistency (e.g. anti-settling agents and plasticizers), the foaming  
15 properties (e.g. antifoaming agents), the lubricating properties (waxes), the adhesion properties, the antistatic properties, etc. According to one embodiment, the UV-Vis radiation curable coating composition described herein further comprise one or more additives selected from the group consisting of thickeners, surfactants, anti-settling agents, plasticizers, antifoaming agents, waxes and mixtures thereof.

20 [078] Additives described herein may be present in the coating composition in amounts and in forms known in the art, including so-called nano-materials where at least one of the dimensions of the additive is in the range of 1 to 1000 nm.

[079] According to one embodiment, the UV-Vis radiation curable coating compositions described herein comprise:

- 25 i) optionally the one or more (meth)acrylate oligomers described herein, preferably the one or more (meth)acrylate oligomers described herein in the total amount described herein;
- ii) the one or more (meth)acrylate monomers, preferably selected from the group consisting of tri(meth)acrylates, tetra(meth)acrylates and mixtures thereof, described herein in the total amount described herein, wherein said one or more monomers are different from the (meth)acrylate oligomers  
30 of i);
- iii) the one or more cyclic ether compounds, preferably selected from the group consisting of epoxides, oxetanes and mixtures thereof, more preferably cycloaliphatic epoxides, oxetanes and mixtures thereof, described herein in the total amount described herein;
- iv) the one or more vinyl ether compounds described herein in the total amount described herein;
- 35 v) the one or more onium photoinitiators described herein in the total amount described herein;
- vi) the one or more photoinitiators selected from the group consisting of alkoxyketones, acetophenones, benzophenones, ketosulfones, benzyl ketals, benzoin ethers, phosphine oxides, phenylglyoxylates, coumarins, camphorquinones and mixtures thereof described herein in the total amount described herein;

vii) the one or more thermoplastic polymers, preferably polyvinyl butyrals (PVB), described herein in the total amount described herein;

viii) the non-spherical magnetic or magnetisable pigment particles, preferably the non-spherical optically variable magnetic or magnetisable pigment particles, described herein in the total amount described

5 herein;

ix) optionally the one or more photosensitizers, when present, said one or more photosensitizers are preferably present in the total amount described herein;

x) optionally the one or more fillers or extenders in the total amount described herein;

xi) optionally the one or more UV stabilizers in the total amount described herein;

10 xii) optionally the one or more color constant coloring components in the total amount described herein;

xiii) optionally the one or more solvents in the total amount described herein;

xiv) optionally the one or more marker substances or taggants and/or one or more machine readable materials described herein; and

15 xv) optionally the one or more additives selected from the group consisting of thickeners, surfactants, anti-settling agents, plasticizers, antifoaming agents, waxes and mixtures thereof.

**[080]** The UV-Vis radiation curable coating compositions described herein may be prepared by dispersing or mixing all the ingredients described herein thus forming liquid compositions. Alternatively, the one or more photoinitiators v) and vi) and the optional one or more photosensitizers ix) may be added to the composition either during the dispersing or mixing step of all other ingredients or may be  
20 added at a later stage, i.e. after the formation of the liquid coating composition.

**[081]** Also described herein are methods for producing optical effect layers (OELs) on substrates, wherein said OELs are based on magnetically oriented non-spherical magnetic or magnetizable pigment particles such as those described herein. The method described herein comprises steps of: a) applying  
25 the UV-Vis radiation curable coating composition described herein on a substrate such as those described herein so as to form a coating layer, b) exposing the coating layer which is in a first state to the magnetic field of a magnetic-field-generating device, thereby orienting at least a part of the non-spherical magnetic or magnetisable pigment particles described herein, and c) hardening the coating layer to a second state so as to fix the non-spherical magnetic or magnetisable pigment particles in their  
30 adopted positions and orientations.

**[082]** The method described herein comprises the step a) of applying the UV-Vis radiation curable coating composition described herein on the substrate described herein so as to form a coating layer, said coating composition being in a first physical state which allows its application as a layer and which is in a not yet hardened (i.e. wet) state wherein the non-spherical magnetic or magnetizable pigment  
35 particles can move and rotate within the binder material. Preferably, the step a) is carried out by a printing process preferably selected from the group consisting of screen printing, rotogravure printing, flexography printing, intaglio printing (also referred in the art as engraved copper plate printing, engraved steel die printing), pad printing and curtain coating, more preferably selected from the group consisting of intaglio printing, screen printing, rotogravure printing, pad printing and flexography printing and still  
40 more preferably screen printing, rotogravure printing, pad printing and flexography printing.

[083] The UV-Vis radiation curable coating composition described herein may be applied on the substrate described herein in the form of the one or more indicia. As used herein, the term "indicia" shall mean discontinuous layers including without limitation codes, symbols, alphanumeric symbols, motifs, geometric patterns (e.g. circles, triangles and regular or irregular polygons), letters, words, numbers, logos, drawings, portraits and combinations thereof. Examples of codes include encoded marks such as an encoded alphanumeric data, a one-dimensional barcode, a two-dimensional barcode, a QR-code and a datamatrix. The one or more indicia described herein may be solids indicia and/or raster indicia.

[084] The method described herein comprises, subsequently to the step a) described herein, the step b) of exposing the coating layer to the magnetic field of a magnetic-field generating device so as to orient at least a part of the non-spherical magnetic or magnetizable pigment particles.

[085] According to one embodiment, the step b) is carried out so as to mono-axially orient at least a part of the magnetic or magnetizable pigment particles described herein.

[086] According to another embodiment wherein the pigment particles are platelet-shaped magnetic or magnetizable pigment particles, the step b) is carried out so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles, preferably so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles to have both their X-axes and Y-axes substantially parallel to the substrate surface.

[087] According to another embodiment wherein the pigment particles are platelet-shaped magnetic or magnetizable pigment particles, the step b) consists of two steps, a first step consisting of exposing the coating layer to the magnetic field of the magnetic-field generating device so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles, and a second step consisting of exposing the coating layer to a magnetic field of a second magnetic-field-generating device so as to mono-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles, wherein said second step is carried out partially simultaneously with, simultaneously with or subsequently to the first step.

[088] For embodiments wherein the method described herein comprises the step of exposing the coating layer to the magnetic field of the magnetic-field generating device described herein so as to bi-axially orient at least a part of the magnetic or magnetizable pigment particle, the coating layer may be subsequently exposed more than one time to said magnetic-field generating device.

[089] In contrast to a mono-axial orientation wherein magnetic or magnetizable pigment particles are orientated in such a way that only their main axis is constrained by the magnetic field, carrying out a bi-axial orientation means that the platelet-shaped magnetic or magnetizable pigment particles are made to orientate in such a way that their two main axes are constrained. That is, each platelet-shaped magnetic or magnetizable pigment particle can be considered to have a major axis in the plane of the pigment particle and an orthogonal minor axis in the plane of the pigment particle. The major and minor axes of the platelet-shaped magnetic or magnetizable pigment particles are each caused to orient according to the magnetic field. Effectively, this results in neighboring platelet-shaped magnetic pigment particles that are close to each other in space to be essentially parallel to each other. Put another way, bi-axial orientation aligns the planes of the platelet-shaped magnetic or magnetizable pigment particles so that the planes of said pigment particles are oriented to be essentially parallel relative to the planes

of neighboring (in all directions) platelet-shaped magnetic or magnetizable pigment particles. The bi-axially orientation of the platelet-shaped magnetic or magnetizable pigment particles described herein results in that the platelet-shaped magnetic or magnetizable pigment particles form a sheet-like structure with their X and Y axes preferably substantially parallel to the substrate surface and are planarized in said two dimensions.

**[090]** Suitable magnetic-field generating devices for mono-axially orienting the non-spherical magnetic or magnetizable pigment particles described herein are not limited and include for example dipole magnets, multipolar magnets such as quadrupolar, hexapolar and octapolar magnets, and combinations thereof. The following devices are provided herein as illustrative examples.

**[091]** Optical effects known as flip-flop effects (also referred in the art as switching effect) include a first printed portion and a second printed portion separated by a transition, wherein pigment particles are aligned parallel to a first plane in the first portion and pigment particles in the second portion are aligned parallel to a second plane. Methods and magnets for producing said effects are disclosed for example in in US 2005/0106367 and EP 1 819 525 B1.

**[092]** Optical effects known as rolling-bar effects as disclosed in US 2005/0106367 may also be produced. A “rolling bar” effect is based on pigment particles orientation imitating a curved surface across the coating. The observer sees a specular reflection zone which moves away or towards the observer as the image is tilted. The pigment particles are aligned in a curving fashion, either following a convex curvature (also referred in the art as negative curved orientation) or a concave curvature (also referred in the art as positive curved orientation). Methods and magnets for producing said effects are disclosed for example in EP 2 263 806 A1, EP 1 674 282 B1, EP 2 263 807 A1, WO 2004/007095 A2, WO 2012/104098 A1, and WO 2014/198905 A2.

**[093]** Optical effects known as Venetian-blind effects may also be produced. Venetian-blind effects include pigment particles being oriented such that, along a specific direction of observation, they give visibility to an underlying substrate surface, such that indicia or other features present on or in the substrate surface become apparent to the observer while they impede the visibility along another direction of observation. Methods and magnets for producing said effects are disclosed for example in US 8,025,952 and EP 1 819 525 B1.

**[094]** Optical effects known as moving-ring effects may also be produced. Moving-ring effects consists of optically illusive images of objects such as funnels, cones, bowls, circles, ellipses, and hemispheres that appear to move in any x-y direction depending upon the angle of tilt of said optical effect layer. Methods and magnets for producing said effects are disclosed for example in EP 1 710 756 A1, US 8,343,615, EP 2 306 222 A1, EP 2 325 677 A2, WO 2011/092502 A2, US 2013/0084411, WO 2014 108404 A2 and WO2014/108303 A1.

**[095]** Optical effects providing an optical impression of a pattern of moving bright and dark areas upon tilting said effect may also be produced. Methods and magnets for producing said effects are disclosed for example in WO 2013/167425 A1.

**[096]** Optical effects providing an optical impression of a loop-shaped body having a size that varies upon tilting said effect may also be produced. Methods and magnets for producing these optical effects are disclosed for example in WO 2017/064052 A1, WO 2017/080698 A1 and WO 2017/148789 A1.

**[097]** Optical effects providing an optical impression of one or more loop-shaped bodies having a shape that varies upon tilting the optical effect layer may also be produced. Methods and magnets for producing said effects are disclosed for example in WO 2018/054819 A1.

5 **[098]** Optical effects providing an optical impression of a moon crescent moving and rotating upon tilting may also be produced. Methods and magnets for producing said effects are disclosed for example in WO 2019/215148 A1.

**[099]** Optical effects providing an optical impression of a loop-shaped body having a size and shape that varies upon tilting may be produced. Methods and magnets for producing said effects are disclosed for example in the co-pending PCT patent application WO 2020/052862 A1.

10 **[0100]** Optical effects providing an optical impression of an ortho-parallactic effect, i.e. in the present case under the form of a bright reflective vertical bar moving in a longitudinal direction when the substrate is tilted about a horizontal/latitudinal axis or moving in a horizontal/latitudinal direction when the substrate is tilted about a longitudinal axis may be produced. Methods and magnets for producing said effects are disclosed for example in WO 2020/160993 A1.

15 **[0101]** Optical effects providing an optical impression of one loop-shaped body surrounded by one or more loop-shaped bodies, wherein said one or more loop-shaped bodies have their shape and/or their brightness varying upon tilting may be produced. Methods and magnets for producing said effects are disclosed for example in WO 2020/193009 A1.

20 **[0102]** Optical effects providing an optical impression of a plurality of dark spots and a plurality of bright spots moving and/or appearing and/or disappearing not only in a diagonal direction when the substrate is tilted about a vertical/longitudinal axis but also moving and/or appearing and/or disappearing in a diagonal direction when the substrate is tilted may be produced. Methods and magnets for producing said effects are disclosed for example in WO 2021/083808 A1 and WO 2021/083809 A1.

25 **[0103]** Suitable magnetic-field generating devices also include those which may comprise a magnetic plate carrying one or more reliefs, engravings or cut-outs. WO 2005/002866 A1 and WO 2008/046702 A1 are examples for such engraved magnetic plates.

30 **[0104]** Suitable magnetic-field generating devices also include those comprising soft magnetic plates carrying one or more indicia in the form of indentations and/or protrusions or soft magnetic plates comprising one or more voids having the shape of one or more indicia, wherein the orientation step is carried out by forming an assembly of the substrate carrying the coating layer above the soft magnetic plate and wherein said assembly is moved through an inhomogeneous magnetic field of a static magnetic-field-generating device so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles as described in WO 2018/019594 A1 and WO 2018/033512 A1.

35 **[0105]** Suitable magnetic-field generating devices also include those comprising a soft magnetic plate comprising one or more voids for receiving one or more dipole magnets and comprising one or more indentations and/or one or more protrusions forming one or more continuous loop-shaped indicia and/or one or more discontinuous loop-shaped indicia as described in WO 2020/025218 A1 or a soft magnetic assembly comprising one or more voids and one or more dipole magnets being disposed within the one or more voids and/or are facing said one or more voids and/or one or more pairs of two dipole magnets

being disposed below the soft magnetic plate and being spaced apart from the one or more voids as described in WO 2020/025482 A1.

**[0106]** Suitable magnetic-field generating devices for bi-axially orienting the platelet-shaped magnetic or magnetizable pigment particles described herein are not limited.

- 5 **[0107]** Particularly preferred devices for bi-axially orienting the pigment particles are disclosed in EP 2 157 141 A1. Upon motion of a substrate carrying a coating layer comprising pigment particles, the device disclosed in EP 2 157 141 A1 provides a dynamic magnetic field that changes its direction forcing the pigment particles to rapidly oscillate until both main axes, X-axis and Y-axis, become substantially parallel to the substrate surface, i.e. the pigment particles rotate until they come to the stable sheet-like formation with their X and Y axes substantially parallel to the substrate surface and are planarized in said two dimensions.

- 10 **[0108]** Other particularly preferred devices for bi-axially orienting the pigment particles comprise linear permanent magnet Halbach arrays, i.e. devices comprising a plurality of magnets with different magnetization directions and cylinder devices. Detailed description of Halbach permanent magnets was given by Z.Q. Zhu and D. Howe (Halbach permanent magnet machines and applications: a review, IEE. Proc. Electric Power Appl., 2001, 148, p. 299-308). The magnetic field produced by such a Halbach array has the properties that it is concentrated on one side while being weakened almost to zero on the other side. Linear Halbach arrays are disclosed for example in WO 2015/086257 A1 and WO 2018/019594 A1 and Halbach cylinder devices are disclosed in EP 3 224 055 B1.

- 20 **[0109]** Other particularly preferred devices for bi-axially orienting the pigment particles are spinning magnets, said magnets comprising disc-shaped spinning magnets or magnetic-field generating devices that are essentially magnetized along their diameter. Suitable spinning magnets or magnetic-field generating devices are described in US 2007/0172261 A1, said spinning magnets or magnetic-field generating devices generate radially symmetrical time-variable magnetic fields, allowing the bi-orientation of magnetic or magnetizable pigment particles of a not yet cured coating composition. These magnets or magnetic-field generating devices are driven by a shaft (or spindle) connected to an external motor. CN 102529326 B discloses examples of devices comprising spinning magnets that might be suitable for bi-axially orienting magnetic or magnetizable pigment particles. In a preferred embodiment, suitable devices for bi-axially orienting magnetic or magnetizable pigment particles are shaft-free disc-shaped spinning magnets or magnetic-field generating devices constrained in a housing made of non-magnetic, preferably non-conducting, materials and are driven by one or more magnet-wire coils wound around the housing. Examples of such shaft-free disc-shaped spinning magnets or magnetic-field generating devices are disclosed in WO 2015/082344 A1, WO 2016/026896 A1 and WO2018/141547 A1.

- 30 **[0110]** Other particularly preferred devices for bi-axially orienting the pigment particles are shown in WO 2021/239607 A1, Fig. 3A and comprise a) at least a first set (S1) and a second set (S2), each of the first and second sets (S1, S2) comprising one first bar dipole magnet having its magnetic axis oriented to be substantially parallel to the substrate during the magnetic orientation and two second bar dipole magnets having their magnetic axes oriented to be substantially perpendicular to the substrate;

and b) a pair (P1) of third bar dipole magnets having their magnetic axes oriented to be substantially parallel to the substrate such as those disclosed in WO 2021/239607 A1.

**[0111]** The method described herein comprises the step c) of hardening the coating layer to a second state so as to fix the non-spherical magnetic or magnetisable pigment particles in their adopted positions and orientations. Said hardening step is carried out with the one or more light sources so as to cure the coating layer, wherein said one or more light sources are preferably selected from the group consisting of mercury lamps (preferably medium-pressure mercury lamps), UV-LED lamps and sequences thereof described herein, so as to form one or more optical effect layers (OELs) described herein. Typical sequences include the use of one or more UV-LED lamps in a first step to partially cure the UV-Vis radiation curable coating composition and one or more medium-pressure mercury lamps in a second step. Mercury lamps advantageously emit on a wide range of wavelengths in the UV-A, UV-B and UV-C range. The step d) of hardening the coating layer described herein may be carried out partially simultaneously with or subsequently to the step b) described herein. By "partially simultaneously", it is meant that both steps are partly performed simultaneously, i.e. the times of performing each of the steps partially overlap. In the context described herein, when the hardening/curing step c) is performed partially simultaneously with the orientation step b), it must be understood that curing becomes effective after the orientation of the non-spherical magnetic or magnetizable pigment particles in the coating layer before the complete or partial curing.

**[0112]** The present invention provides the methods described herein to produce optical effect layers (OELs) described herein and substrates comprising one or more optical effect layers (OELs) obtained thereof. The substrate described herein is preferably selected from the group consisting of papers or other fibrous materials (including woven and non-woven fibrous materials), such as cellulose, paper-containing materials, glasses, metals, ceramics, plastics and polymers, metallized plastics or polymers, composite materials and mixtures or combinations of two or more thereof. Typical paper, paper-like or other fibrous materials are made from a variety of fibers including without limitation abaca, cotton, linen, wood pulp, and blends thereof. As is well known to those skilled in the art, cotton and cotton/linen blends are preferred for banknotes, while wood pulp is commonly used in non-banknote security documents. According to another embodiment, the substrate described herein is based on plastics and polymers, metallized plastics or polymers, composite materials and mixtures or combinations of two or more thereof. Suitable examples of plastics and polymers include polyolefins such as polyethylene (PE) and polypropylene (PP) including biaxially oriented polypropylene (BOPP), polyamides, polyesters such as poly(ethylene terephthalate) (PET), poly(1,4-butylene terephthalate) (PBT), poly(ethylene 2,6-naphthoate) (PEN) and polyvinylchlorides (PVC). Spunbond olefin fibers such as those sold under the trademark Tyvek® may also be used as substrate. Typical examples of metallized plastics or polymers include the plastic or polymer materials described hereabove having a metal disposed continuously or discontinuously on their surface. Typical examples of metals include without limitation aluminum (Al), chromium (Cr), copper (Cu), gold (Au), silver (Ag), alloys thereof and combinations of two or more of the aforementioned metals. The metallization of the plastic or polymer materials described hereabove may be done by an electrodeposition process, a high-vacuum coating process or by a sputtering process. Typical examples of composite materials include without limitation multilayer structures or

laminates of paper and at least one plastic or polymer material such as those described hereabove as well as plastic and/or polymer fibers incorporated in a paper-like or fibrous material such as those described hereabove. Of course, the substrate can comprise further additives that are known to the skilled person, such as fillers, sizing agents, whiteners, processing aids, reinforcing or wet strengthening agents, etc. When the OELs are used for decorative or cosmetic purposes including for example fingernail lacquers, said OEL may be produced on other type of substrates including nails, artificial nails or other parts of an animal or human being.

**[0113]** Also described herein are methods of manufacturing a security document or a decorative element or object, comprising a) providing a security document or a decorative element or object, and b) providing the one or more optical effect layers described herein, in particular such as those obtained by the method described herein, so that it is comprised by the security document or decorative element or object.

**[0114]** Should the OEL produced according to the present invention be on a security document or article, and with the aim of further increasing the security level and the resistance against counterfeiting and illegal reproduction of said security document or article, the substrate may comprise printed, coated, or laser-marked or laser-perforated indicia, watermarks, security threads, fibers, planchettes, luminescent compounds, windows, foils, decals and combinations of two or more thereof. With the same aim of further increasing the security level and the resistance against counterfeiting and illegal reproduction of security documents and articles, the substrate may comprise one or more marker substances or taggants and/or machine readable substances (e.g. luminescent substances, UV/visible/IR absorbing substances, magnetic substances and combinations thereof).

**[0115]** If desired, a primer layer may be applied to the substrate prior to the step a). This may enhance the quality of the OEL described herein or promote adhesion. Examples of such primer layers may be found in WO 2010/058026 A2.

**[0116]** The substrate comprising the one or more OELs described herein may be embossed such as for example with an intaglio plate as described for example in WO 2012/025206 A2 and WO 2019/233624 A1.

**[0117]** The OEL described herein may be used in combination with holograms, microlenses and/or micromirrors as described in WO 2020/244805 A1, EP 3 254 863 A1, US 2008/0160226, US 2005/0180020 and EP 2 284 017 A1.

**[0118]** With the aim of increasing the durability through soiling or chemical resistance and cleanliness and thus the circulation lifetime of a security document, article or a decorative element or object comprising the OEL obtained by the method described herein, or with the aim of modifying their aesthetical appearance (e.g. optical gloss), one or more protective layers may be applied on top of the OEL. When present, the one or more protective layers are typically made of protective varnishes. Protective varnishes may be radiation curable compositions, thermal drying compositions or any combination thereof. Preferably, the one or more protective layers are radiation curable compositions, more preferable UV-Vis curable compositions. The protective layers are typically applied after the formation of the OEL.

**[0119]** The OEL described herein may be provided directly on a substrate on which it shall remain

permanently (such as for banknote applications). Alternatively, an optical effect layer may also be provided on a temporary substrate for production purposes, from which the OEL is subsequently removed. This may for example facilitate the production of the optical effect layer (OEL), particularly while the binder material is still in its fluid state. Thereafter, after curing of the coating composition for the production of the OEL, the temporary substrate may be removed from the OEL.

**[0120]** Alternatively, in another embodiment an adhesive layer may be present on the substrate comprising the OEL, said adhesive layer being on the side of the substrate opposite to the side where the OEL is provided or on the same side as the OEL and on top of the OEL. Therefore, an adhesive layer may be applied to the OEL or to the substrate, said adhesive layer being applied after the curing step has been completed. Such an article may be attached to all kinds of documents or other articles or items without printing or other processes involving machinery and rather high effort. Alternatively, the substrate described herein comprising the OEL described herein may be in the form of a transfer foil, which can be applied to a document or to an article in a separate transfer step. For this purpose, the substrate is provided with a release coating, on which the OELs are produced as described herein. One or more adhesive layers may be applied over the so produced optical effect layer.

**[0121]** Also described herein are substrates comprising more than one, i.e. two, three, four, etc. optical effect layers (OELs) obtained by the method described herein.

**[0122]** Also described herein are articles, documents, in particular security documents, decorative elements and decorative objects comprising the optical effect layer (OEL) produced according to the present invention. The articles, in particular security documents, decorative elements or objects, may comprise more than one (for example two, three, etc.) OELs produced according to the present invention.

**[0123]** As mentioned hereabove, the OEL produced according to the present invention may be used for decorative purposes as well as for protecting and authenticating a security document.

**[0124]** Typical examples of decorative elements or objects include without limitation luxury goods, cosmetic packaging, automotive parts, electronic/electrical appliances, furniture and fingernail articles.

**[0125]** Security documents include without limitation value documents and value commercial goods. Typical example of value documents include without limitation banknotes, deeds, tickets, checks, vouchers, fiscal stamps and tax labels, agreements and the like, identity documents such as passports, identity cards, visas, driving licenses, bank cards, credit cards, transactions cards, access documents or cards, entrance tickets, public transportation tickets, academic diploma or titles and the like, preferably banknotes, identity documents, right-conferring documents, driving licenses and credit cards. The term "value commercial good" refers to packaging materials, in particular for cosmetic articles, nutraceutical articles, pharmaceutical articles, alcohols, tobacco articles, beverages or foodstuffs, electrical/electronic articles, fabrics or jewelry, i.e. articles that shall be protected against counterfeiting and/or illegal reproduction in order to warrant the content of the packaging like for instance genuine drugs. Examples of these packaging materials include without limitation labels, such as authentication brand labels, tamper evidence labels and seals. It is pointed out that the disclosed substrates, value documents and value commercial goods are given exclusively for exemplifying purposes, without restricting the scope of the invention.

[0126] Alternatively, the optical effect layer (OEL) described herein may be produced onto an auxiliary substrate such as for example a security thread, security stripe, a foil, a decal, a window or a label and consequently transferred to a security document in a separate step.

[0127] The skilled person can envisage several modifications to the specific embodiments described above without departing from the spirit of the present invention. Such modifications are encompassed by the present invention.

[0128] Further, all documents referred to throughout this specification are hereby incorporated by reference in their entirety as set forth in full herein.

## 10 EXAMPLES

[0129] The present invention is now described in more details with reference to non-limiting examples. The Examples (E1-E2) and the Comparative Examples (C1-C3) were prepared with the UV-Vis radiation curable coating compositions described in Table 1 and provide more details for the compositions according to the present invention.

[0130] The UV-Vis radiation curable coating compositions shown in Table 1 were used to prepare two different sets of samples: a first set was prepared to assess the magnetic orientation process as applied with the different compositions and the visual quality of the so-obtained OEL (Fig. 1); and a second set of samples was prepared to assess the mechanical properties and resistance of the printed and hardened layers (Figs. 2 and 3).

20 **Table 1**

|                                                                                                                            | E1    | E2    | C1 <sup>1)</sup> | C2 <sup>2)</sup> | C3 <sup>3)</sup> |
|----------------------------------------------------------------------------------------------------------------------------|-------|-------|------------------|------------------|------------------|
| Uvacure 1500<br>7-oxabicyclo[4.1.0]hept-3-ylmethyl 7-oxabicyclo[4.1.0]heptane-3-carboxylate)<br>(Cytec) [CAS Nr 2386-87-0] | 33.05 | 33.05 | 37.2             | 42.5             |                  |
| Diethylene glycol divinyl ether (BASF) [CAS Nr 764-99-8]                                                                   | 10    | 10    | 4.2              | 4.2              |                  |
| UviCure S130; 3-ethyloxetane-3-methanol (Lambson) [CAS Nr 3047-32-3]                                                       | 3.9   | 3.9   | 4.2              | 4.2              |                  |
| MIRAMER M4004; ethoxylated pentaerythritol tetraacrylate (Rahn) [CAS Nr 51728-26-8]                                        | 13.9  | 13.9  | 16.7             | 15               |                  |
| EBECRYL® 2959: epoxy acrylate oligomer (Allnex)                                                                            | 7.8   | 7.8   |                  | 8.4              | 28               |
| Poylol R4631 (Perstrorp) ethoxylated and propoxylated pentaerythritol [no CAS 30374-35-7]                                  |       |       | 8.3              |                  |                  |
| Trimethylolpropane triacrylate monomer                                                                                     |       |       |                  |                  | 19.5             |
| Tripropyleneglycol diacrylate monomer                                                                                      |       |       |                  |                  | 20               |
| Aerosil 200 (Evonik)                                                                                                       | 1.6   | 1.6   | 1.7              | 1.7              | 1                |
| TEGO® Airex 900 (Evonik)                                                                                                   | 1.85  | 1.85  | 2.1              | 2                |                  |

|                                                                         | E1        | E2   | C1 <sup>1)</sup> | C2 <sup>2)</sup> | C3 <sup>3)</sup> |
|-------------------------------------------------------------------------|-----------|------|------------------|------------------|------------------|
| Propylene carbonate [no CAS 108-32-7]                                   | 1.4       | 1.4  | 1.5              | 1.5              |                  |
| BYK® 371 (BYK)                                                          |           |      |                  |                  | 2                |
| Tego Foamex N (Evonik)                                                  |           |      |                  |                  | 2                |
| Genorad 16 (Rahn)                                                       |           |      |                  |                  | 1                |
| Omnicat 440 (IGM)                                                       | 2.8       | 2.8  | 3.4              | 3                |                  |
| Omnirad 1173 (IGM)                                                      | 0.9       | 0.9  | 3.8              | 1                |                  |
| Genocure® ITX (Rahn)                                                    |           |      | 0.4              |                  |                  |
| Speedcure TPO-L (Lambson)                                               |           |      |                  |                  | 2                |
| Irgacure® 500 (IGM)                                                     |           |      |                  |                  | 6                |
| Genocure® EPD (Rahn)                                                    |           |      |                  |                  | 2                |
| 7-layer colorshifting magnetic pigment particles (*)                    | 16.5      | 16.5 | 16.5             | 16.5             | 16.5             |
| VINNOL(R) H14/36 (Wacker)<br>copolymer vinyl chloride and vinyl acetate | 6.3       |      |                  |                  |                  |
| S-LEC BL10 (SIKISUI)<br>polyvinyl butyral                               |           | 6.3  |                  |                  |                  |
| Viscosity (mPa.s)                                                       | 2035      | 2392 | 1230             | 760              | 710              |
| Dry Crumpling assessment                                                | Excellent | Good | ---              | Failed           | Failed           |
| Washing test (60°C)                                                     | Good      | Good | ---              | Failed           | ---              |

(\*) green-to-blue colorshifting magnetic pigment particles having a flake shape (platelet-shaped magnetic pigment particles) of diameter d50 of about 11 µm and thickness about 1 µm, obtained from Viavi Solutions, Santa Rosa, CA.

- 1) C1 composition based on WO 2021/175 907, Table 3A-2, and adjusted to comprise equivalent wt% of magnetic pigment particles
- 2) C2 composition based on WO 2024/028 408, Table 1A, Compos SP1a
- 3) C3 composition based on WO 2021/239607, Table 1

#### **First set of samples: magnetic orientation quality test (Fig. 1)**

- 10 **[0131]** To ensure the same process conditions for the Examples E1-E2 and the Comparative Examples C1-C3, the five UV-Vis radiation curable coating compositions of Table 1 were applied colinearly side-by-side onto a white fiduciary paper (dimensions: 17.5 cm x 14.5 cm, from Louisenthal) using a pipette to form a line (total length of about 125 mm) by hand-coating and were simultaneously oriented using the single magnetic assembly shown in Fig. 4.
- 15 **[0132]** About 1 ml of each of the UV-Vis radiation curable coating compositions of Table 1 was independently applied as a line (length of about 25 mm) using a disposable laboratory pipette. The five UV-Vis radiation curable coating compositions were then semi-automatically drawn simultaneously using a K-Control Coater Model 101 and K Paint Applicator (RK PRINTCOAT INSTRUMENTS) (speed 3) equipped with a closed-wound K-bar HC 3 (about 24 µm thick wet deposit).
- 20 **[0133]** The substrate carrying the applied layers made of the five UV-Vis radiation curable coating

compositions of Table 1 was disposed on the magnetic assembly described herein and schematically illustrated in Figs 4. The magnetic assembly comprised a non-magnetic holder and four dipole magnets. The four dipole magnets had each the following dimensions: length L4 of 30 mm, width L5 of 24 mm and a thickness L6 of 8.5 mm (Plastic-bonded NdFeB magnet produced by molding, BMNpi-80/48 Mold from Bomatec AG, CH-8181 Höri). Each of the four dipole magnets had a magnetic axis being substantially parallel to its width and substantially parallel to the substrate surface. The four dipole magnets were disposed side-by-side in the non-magnetic holder with their magnetic axis being parallel with each other and with their North pole pointing in a same direction. The non-magnetic holder had the following dimensions: length L1 of 140 mm, width L2 of 60 mm and a thickness L3 of 17.95 mm and was made of polyphenylene sulfide (PPS). The upper surface of the holder (i.e. the surface facing the substrate) was curved to be flushed when arranged on a magnetic cylinder with the surface of the magnetic cylinder.

[0134] The distance (d) between the top surface of the dipole magnets and the top surface of the non-magnetic holder (also corresponding to the distance between the top surface of the dipole magnets and the substrate) was 3.35 mm.

[0135] The so-obtained magnetic orientation pattern of the magnetic pigment particles was then, partially simultaneously with the orientation step (i.e. while the substrate carrying the coating layers made of the five UV-Vis radiation curable coating compositions was still in the magnetic field), fixed by exposing the layers comprising the pigment particles to curing using a Fe-doped Hg-lamp (150 W/cm from IST; two passes at a speed of 100 m/min).

[0136] The so-obtained OELs of the Examples E1-E2 and of the Comparative Examples C1-C3 are shown in Fig. 1. As illustrated in Fig. 1, the OELs E1-E2 and C2-C3 were well defined, exhibited an eye-catching effect and displayed a bright and sharp line whereas the comparative OEL C1 was blurred and not well defined. As shown in Fig. 1, the comparative composition C1, which is known to be used to produce security features comprising leafing pigments, is not suitable for the production of OELs and no further assessments of C1 were carried out.

#### **Second set of samples**

[0137] The UV-Vis radiation curable coating compositions E1-E2 and C2-C3 of Table 1 were independently applied onto a white fiduciary paper (6 cm x 6 cm, from Louisenthal) (x20), said application being carried out by hand screen printing using a 90T screen so as to form a coating layer having a thickness of about 20 µm and having a shape of a disc surrounded by six circles with the following overall dimensions: 30 mm x 22 mm.

[0138] The substrates carrying the coating layer made of the UV-Vis radiation curable coating composition were independently placed on a dipole magnet (Plastic-bonded NdFeB magnet produced by molding, BMNpi-80/48 Mold from Bomatec AG, CH-8181 Höri), having the following dimensions length 30 mm x width 24 mm x thickness 8.5 mm, and having a magnetic axis being parallel to the substrate surface. The so-obtained magnetic orientation pattern of the magnetic pigment particles was then, partially simultaneously with the orientation step (i.e. while the substrate carrying the respective coating layer was still in the magnetic field), fixed by exposing the layers comprising the pigment

particles to curing using a Fe-doped Hg-lamp (150 W/cm from IST; two passes at a speed of 100m/min).

[0139] The so-obtained OELs of the Examples E1 and E2 and of the Comparative Examples C2-C3 were highly dynamic, exhibited a well-defined and eye-catching effect and displayed a bright and sharp line which was moving up and down upon tilting of the OEL. The OEL of the Comparative Example C1 was not well defined and did not display a sharp line.

**Mechanical resistance test: dry crumpling test (Fig. 2)**

[0140] Each sample made from the compositions E1-E2 and C2-C3 was independently submitted to a dry crumpling test using a IGT NBS Crumpling Device from IGT Testing Systems according to the following process.

[0141] Each sample was independently wound up along one of its edges with the OEL facing the interior of the roll. The resulting reel was introduced in the crumpling device and the device plunger was introduced. The sample was extracted from the device, unrolled and the process was repeated along the three other sides of the substrate.

[0142] The OEL made from Example E1 was rated as excellent, meaning that no significant visible change was observed and the OEL remained intact after the test with no observable substrate within the layer (Fig. 2). The OEL made from Example E2 was rated as good, meaning that only a slight damage of the layer was observed. The OELs made from Comparative Examples C2-C3 were rated as bad, meaning that a considerable damage of the layer was observed.

**Mechanical resistance test: washing machine test (Fig. 3)**

[0143] Each sample made from the compositions E1-E2 and C2 was submitted to a washing machine test according to the following process. C1 and C3 were not evaluated because they failed at least one of the previous tests.

[0144] Each sample was independently inserted in a washing glove and fixed with two needles. The washing glove with the sample was washed in a washing machine at 60°C for 1.5 hour with a phosphate-free washing powder (spin-drying speed of 800 rpm). The samples were removed from the washing glove and dried between two glass plates at 60°C in an oven for one hour.

[0145] The OELs made from Examples E1-E2 were rated as good, meaning only a slight damage of the layer was observed. The OEL made from Comparative Example C2 was rated as bad, meaning that a considerable damage of the layer was observed (Fig. 3).

**CLAIMS**

1. A UV-Vis radiation curable coating composition for producing an optical effect layer (OEL), the composition comprising
    - 5 i) optionally one or more (meth)acrylate oligomers in a total amount between about 0 wt.% and about 10 wt.%, preferably between about 1 wt.% and about 10 wt.%;
    - ii) one or more (meth)acrylate monomers, preferably selected from the group consisting of tri(meth)acrylates, tetra(meth)acrylates and mixtures thereof, in a total amount between about 1 wt.% and about 20 wt.%, wherein said monomers are different from the (meth)acrylate oligomers of i);
    - 10 iii) one or more cyclic ether compounds, preferably selected from the group consisting of epoxides, oxetanes and mixtures thereof, more preferably cycloaliphatic epoxides, oxetanes and mixtures thereof, in a total amount between about 5 wt.% and about 40 wt.%;
    - iv) one or more vinyl ether compounds in a total amount between about 10 wt.% and about 50 wt.%;
    - 15 v) one or more onium photoinitiators in a total amount between about 0.1 wt.% and about 10 wt.%;
    - vi) one or more photoinitiators selected from the group consisting of alkoxyketones, acetophenones, benzophenones, ketosulfones, benzyl ketals, benzoin ethers, phosphine oxides, phenylglyoxylates, coumarins, camphorquinones and mixtures thereof in a total amount between about 0.1 wt.% and about 10 wt.%;
    - 20 vii) one or more thermoplastic polymers in a total amount between about 1 wt.% and about 20 wt.%; and
    - viii) non-spherical magnetic or magnetisable pigment particles in a total amount between about 1wt.% and about 40 wt.%,

the weight percents being based on the total weight of the UV-Vis radiation curable coating composition.

  - 25
2. The UV-Vis radiation curable coating composition according to claim 1, wherein
    - the one or more (meth)acrylate oligomers i) are present in a total amount between about 2 wt.% and 5 wt.%;
    - 30 the one or more (meth)acrylate monomers ii) are present in a total amount between about 2 wt.% and 15 wt.%;
    - the one or more cyclic ether compounds iii) are present in a total amount between about 10 wt.% and 35 wt.%;
    - the one or more vinyl ether compounds iv) are present in a total amount between about 15 wt.% and 40 wt.%;
    - 35 the one or more onium photoinitiators v) are present in a total amount between about 1 wt.% and 5 wt.%;
    - the one or more photoinitiators vi) are present in a total amount between about 1 wt.% and 5 wt.%;
    - the one or more thermoplastic polymers vii) are present in a total amount between about 3 wt.% and 15 wt.%; and
    - 40

the non-spherical magnetic or magnetisable pigment particles viii) are present in a total amount between about 3 wt.% and 35 wt.%;

the weight percents being based on the total weight of the UV-Vis radiation curable coating composition.

5

3. The UV-Vis radiation curable coating composition according to claim 1 or 2, wherein at least one of the one or more thermoplastic polymers is polyvinyl butyral (PVB) and/or polyvinyl chloride (PVC).

10

4. The UV-Vis radiation curable coating composition according to any one of claims 1 to 3, wherein the non-spherical magnetic or magnetisable pigment particles are non-spherical optically variable magnetic or magnetisable pigment particles, preferably wherein the non-spherical optically variable magnetic or magnetisable pigment particles are selected from the group consisting of magnetic thin-film interference pigment particles, magnetic cholesteric liquid crystal pigment particles, interference coated pigment particles comprising a magnetic material and mixtures of two or more thereof.

15

5. The UV-Vis radiation curable coating composition according to any one of claims 1 to 4, further comprising from about 0.1 wt.% to about 5 wt.% of one or more photosensitizers, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition.

20

6. The UV-Vis radiation curable coating composition according to any one of claims 1 to 5, further comprising from about 0.1 wt.% to about 10 wt.% of one or more fillers or extenders, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition.

25

7. The UV-Vis radiation curable coating composition according to any one of claims 1 to 6, further comprising from about 0.1 wt.% to about 10 wt.% of one or more UV stabilizers, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition.

30

8. The UV-Vis radiation curable coating composition according to any one of claims 1 to 7, further comprising from about 0.05 wt.% to about 5 wt.% of one or more color constant coloring components, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition.

35

9. The UV-Vis radiation curable coating composition according to any one of claims 1 to 8, further comprising one or more marker substances or taggants and/or one or more machine readable materials.

40

10. The UV-Vis radiation curable coating composition according to any one of claims 1 to 9, further comprising one or more solvents in a total amount less than 15 wt.%, the weight percents being based on the total weight of the UV-Vis radiation curable coating composition.

11. The UV-Vis radiation curable coating composition according to any one of claims 1 to 10, further comprising one or more additives selected from the group consisting of thickeners, surfactants, anti-settling agents, plasticizers, antifoaming agents, waxes and mixtures thereof.
- 5 12 A method for producing an optical effect layer (OEL) comprising the steps of:
- a) applying the UV-Vis radiation curable coating composition recited in any one of claims 1 to 11 on a substrate so as to form a coating layer,
  - b) exposing the coating layer which is in a first state to the magnetic field of a magnetic-field-generating device, thereby orienting at least a part of the non-spherical magnetic or magnetisable pigment particles,
  - 10 c) hardening the coating layer to a second state so as to fix the non-spherical magnetic or magnetisable pigment particles in their adopted positions and orientations.
13. The method according to claim 12, wherein the hardening step c) is carried out partially
- 15 simultaneously with step b).
14. The method according to claim 12 or 13, wherein
- the step b) of exposing the coating layer to the magnetic field of the magnetic-field generating device is carried out so as to mono-axially orient at least a part of the non-spherical magnetic or magnetizable pigment particles, or
- 20 wherein the non-spherical magnetic or magnetizable pigment particles are platelet-shaped magnetic or magnetizable pigment particles and wherein the step b) of exposing the coating layer to the magnetic field of the magnetic-field generating device is carried out so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles, or
- 25 wherein the non-spherical magnetic or magnetizable pigment particles are platelet-shaped magnetic or magnetizable pigment particles and wherein the step b) of exposing the coating layer to the magnetic field of the magnetic-field generating device consists of two steps, a first step consisting of exposing the coating layer to the magnetic field of the magnetic-field generating device so as to bi-axially orient at least a part of the platelet-shaped magnetic or magnetizable pigment particles, and
- 30 a second step consisting of exposing the coating layer to a magnetic field of a second magnetic-field-generating device so as to mono-axially orient at least a part of the platelet-shaped magnetic or magnetizable particles, wherein said second step is carried out partially simultaneously with, simultaneously with or subsequently to the first step.
- 35 15. The method according to any of claims 12 to 14, wherein the step a) of applying the UV-Vis radiation curable coating composition is carried out by a process selected from the group consisting of screen printing, rotogravure printing, pad printing and flexography printing.
- 40